SPATIAL AND TEMPORAL

ASPECTS OF SASKATCHEWAN FIELD SHELTERBELTS,

1949-98

A Thesis Submitted to the College of
Graduate Studies and Research in
Partial Fulfillment of the Requirements
for the Degree of Master of Science
in the Department of Geography
University of Saskatchewan
Saskatoon

By

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Abstract

Between 1949 and 1998, the Canadian Government dispensed millions of trees to Saskatchewan producers for soil conservation and agricultural enhancement purposes. A dearth of literature discussing geographical patterns of use, and producer motivation for employing shelterbelts, has necessitated a survey of Saskatchewan's windbreak planting history. Official tree application records have revealed several spatial and temporal patterns of shelterbelt use. A primary band of high shelterbelt concentration extends between Saskatoon and Swift Current, while the eastern portion of the province shows significantly fewer field windbreaks. Province-wide use peaked in the late 1980s/early 1990s, although many notable regional planting efforts have occurred at different times throughout the study period. *Caragana arborescens* and *Fraxinus pennsylvanica* have proven to be universal shelterbelt species, while other types including willows and conifers are more geographically and historically restricted in use. Regional climatic, edaphic, and geomorphic characteristics, past meteorological and agrarian policy historical-contextual events, as well as high erosion risk agricultural techniques such as tilled-summerfallow, have combined with social-economic and policy factors to influence landowner field shelterbelt decision-making.

Acknowledgements

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Abbreviations

ADD	Agriculture, Development and Diversification
BSk	'cold steppe' (Köppen climate classification)
CI	Crop Insurance
CLI	Canada Land Inventory
CWB	Canadian Wheat Board
Dfb	'snowy forest-warm summer' (Köppen climate classification)
ERDA	Economic and Regional Development Agreement
FCC	Farm Credit Corporation
NISA	Net Income Stabilization Act
NSCP	National Soil Conservation Program
NTS	National Topographic System
OAC	Ontario Agriculture College
PFRA	Prairie Farm Rehabilitation Administration (also: Prairie Farm Rehabilitation Act)
Rge.	Range
RM	rural municipality
SAF	Saskatchewan Agriculture and Food
Sec.	Section

SOS	Save Our Soils Program
SRM	Saskatchewan Rural Municipality
Twp.	Township
WGSA	Western Grain Stabilization Act

Chapter 1
Introduction

1.1 Preamble

The 1991 Census of Agriculture recorded 60,840 farms operating in Saskatchewan. Of these, 10,755 reported a total 33,947 kilometres of shelterbelts employed for the expressed purpose of conserving soil. In that year alone, the Canada Department of Agriculture's Prairie Farm Rehabilitation Administration (PFRA) supplied five million field shelterbelt trees to Saskatchewan producers; enough to create 3,150 kilometres. This was not an isolated occurrence. Under varying administrations, a similar process has occurred each year since 1892, whereby trees destined for field shelter have been distributed *en masse*. The consequence of those efforts is a distinct alteration of the prairie landscape, and there are now few places where distinctive lines of trees are not readily visible.

That shelterbelts have been so thoroughly embraced by producers in a region not naturally conducive to tree propagation raises the question of why this has been the case. This study has been formulated to investigate the phenomenon from a geographical perspective; that is, the spatial and temporal patterns of shelterbelt use are analyzed and explained in terms of the determining variables.

1.2 Purpose of Research and Objectives

In the past, Canadian and foreign governments have given field shelterbelts high priority as a beneficial rural feature and have funded a substantial body of research into them. Most published studies concentrate on technical aspects of windbreaks such as aerodynamic theory, propagation and pathological concerns, or species adaptability. Unfortunately, there is a dearth of literature addressing questions of geographical patterns of use, and an even lesser amount discussing human motivation to employ them.

To determine why shelterbelts have been so widely adopted in Saskatchewan is the primary purpose of the study presented here. However, other queries of interest have also been identified. An important one simply asks where shelterbelts are located. Despite distributing millions of trees to Saskatchewan farms, the PFRA has kept only informal records of planting concentration. Specific locations receiving shelterbelt trees have been carefully annotated by the PFRA as part of its processing of tree requests. However, only general statistics have been generated from this spatial data, and distribution detail remains undefined. Another area of subjective interest, only partially documented in literature, is the appropriateness of shelterbelt placement; that is, are they being used where they are beneficial, or conversely, are some situated in locations without obvious need for them. To address these queries, a description of Saskatchewan shelterbelt characteristics, (intended purpose, application design, and species used), is appropriate. Also of interest, relating to concerns emphasized in literature of the potential for widespread shelter deterioration and abandonment, are issues of windbreak health and landowner support.

Finally, once the attributes of Saskatchewan shelterbelts have been assessed, the question "why?" can be contemplated. There are many reasons to establish field shelterbelts. However, doing so involves substantial long-term agricultural investment for which there is no immediate return. As such, it is advantageous to identify potential causal links between physical-environmental conditions and human-use systems, whereby windbreaks are viewed as an appropriate response.

The reasons stated above for conducting a study of Saskatchewan's field shelterbelts are effectively condensed into four objectives applicable to this thesis:

1) To determine where field shelterbelts are concentrated within Saskatchewan and if any spatial distribution patterns are evident.

2) To quantify historical application including the amount of shelter planted versus that removed.

3) To describe Saskatchewan shelterbelt characteristics in terms of purpose, design, and species composition.

4) To explain why shelterbelts have been placed in particular locations by investigating and identifying influential determining factors.

This thesis proposes that spatial differentiation in Saskatchewan field shelterbelt distribution and character does exist, and that by addressing the above objectives, this variation will be proven. Particularly complex aspects, such as landowner motivation and rationale for establishing shelterbelts, are beyond the scope of this study and are therefore not analyzed. However, the research achieves its main goal in providing a useful *overall* depiction of field shelterbelt history and use.

Chapter 2
Analytical Framework

2.1 Organization

With the stated objectives in mind, an organizational framework has been devised. Chapter 3 presents a background to shelterbelt use. It includes a depiction of the study area's natural and social characteristics, and the history of official promotion of windbreaks in Saskatchewan. The basic theory of shelterbelts is discussed in Chapter 4. Chapter 5 illustrates spatial and historical field shelterbelt distribution patterns with a series of maps. These comprise the core of the thesis and have been created for a historical time-frame spanning the fifty years prior to 1999. Descriptions of notable Saskatchewan shelterbelt characteristics are included.

The 'provincial'-level scale of the Chapter 5 distribution mapping provides insufficient detail to answer some of the questions posed by the objectives. Therefore, five case studies examining shelterbelt qualities at larger scales are documented in Chapter 6. In each case, two larger scales are used. One of these, the 'regional' level, represents land blocks one degree of latitude by two degrees of longitude. This unit size is advantageous as it corresponds well with National Topographic System (NTS) and Canada Land Inventory (CLI) mapping. A third scale, the 'local' level, allows investigation of finer detail within township-size quadrats (each measuring six miles by six miles). This is the shelterbelt density mapping resolution unit and a township's 36 square miles facilitate field surveying. Five regional areas, and five local blocks within each, have been selected based on three principal criteria: areas noted in the distribution maps, representation of one of the various physiographic profiles found in Saskatchewan, and, accessibility for field surveying. All regional and corresponding local areas have been named for the towns situated nearest to the 'local' spatial unit. These are: Midale, Cadillac, Davidson-Bladworth, Wilkie-Unity, and Nipawin. In each case, environmental and human-use conditions are provided as background to the location's specific shelterbelt history. To document shelterbelt establishment versus removal, individual windbreaks in each sample township have been charted, using historical aerial photography, and field survey techniques. Where the tree distribution record set is sufficiently complete, historical tree shipments are compared with visible shelterbelts, providing an estimation of the accuracy of the provincial scale maps. More importantly, the township-scale mapping allows one to 'look inside the squares' of the small-scale provincial maps, providing a degree of insight as to how widely-differing actual field characteristics can be equally represented on a smaller-scale map. Finally, based on the results of the provincial *and* local shelterbelt mapping, notable shelterbelt distribution patterns are interpreted with a discussion of the determining factors.

2.2 Data

This thesis incorporates a variety of data including climatic and agricultural statistics, CLI land-use surveys, and social-historical interpretations. However, much of this information is primarily used to supply context for the historical shelterbelt distribution maps which are the primary component of the thesis. The data source of the latter is PFRA shelterbelt tree request records.

Throughout the long period of official shelterbelt tree distribution, thousands of requests have been filed with the PFRA and millions of trees have been shipped. In processing the applications, the PFRA has recorded basic information detailing to whom trees were sent, the applicant's land location, the quantity and species of trees ordered, and the intended shelter use. Until 1981, this information was recorded on paper as each application was processed. Since then, the accounts have been archived digitally. Collectively, these records have permitted the assembly of a province-wide shelterbelt distribution picture without necessitating the use of more costly forms of data such as remotely sensed imagery or ground surveys. Aside from significant cost savings, the use of archived data provides other advantages. Primarily, it is possible to extract much greater detail for aspects such as planting purpose, species, and tree spacing. Additionally, because the record is uninterrupted as opposed to the 'snapshot' characteristic of remotely sensed images and field surveys, more complete temporal variation analysis is possible.

The primary data used in this research comes from both the electronic and index card record sets. The digital database was supplied by the PFRA and required minimal processing. The index card archive, representing thirty-two years of the fifty-year study period, was manually transcribed into a companion database. Figure 2.2.1 and

Table 2.2.1 provide, respectively, a sample PFRA record card and a sample page from the transcribed record set.

For this study, only portions of the paper archive representing 'field'-type shelterbelts were transcribed. Types excluded from the mapping, including the major farm and wildlife categories, have been disregarded because they fall outside the scope of this thesis. Initially, using the digital data-base, RM-resolution maps of both field and farm shelterbelts were produced. These demonstrated the spatial uniformity of farm shelterbelt dispersal as opposed to the more patterned field shelter placement. Simply, farm windbreaks are planted where there are farms and are,

Name
Address
Shaunavon, Sask.
SHIPPING POINT SHAUNAVON RLY.

LAND SE SEC. 32 TWP. 10 RGE. 16 W. 3
LOCATIONS SE¼ SEC. 4 TWP. 11 RGE. 16 W. 3
SOIL TYPE loam, med.
DISTRICT R.M. #108
#4928

PLANTING			DECIDUOUS TREES								EVERGREENS			
Year	Type	Distance	Maple	Ash	American Elm	Siberian Elm	Caragana	Poplar	Willow	TOTAL	Colorado Spruce	White Spruce	Scots Pine	TOTAL
1947	F.S.				600		1650			2,250				
1948	hedge & B.				100		900			1,000				
1949	B.				50		300			350				
1952	F.S.						5300			5,300				
1953	F.S.		1050				6000			7,050				
1956											50	50		100
1960												30		30
1961												30		30
1962											50			50
1960	F.S.						1325			1,325		30		30
1963	F.S.	1 M.					2650			2,650				
1974	F.S.	1 mi.					2,500							2,500

PA 232

SEE REVERSE SIDE FOR REMARKS

Figure 2.2.1: Example of a PFRA archive record card.

therefore, not included in the township-scale mapping. The preliminary maps may be consulted in Appendix A.

One benefit of manual data transcription is that certain qualities of the original record keeping are readily apparent. This is especially helpful as it alerts

Table 2.2.1 Sample page of the transcribed PFRA archive.

RM	Sec	Twp	Rge	W.	Year	Type	Dist.	Number	Species
134	3	15	5	3	80	Field	1	600	Ash
134	3	15	5	3	80	Field	"	600	American Elm
134	3	15	5	3	80	Field	"	1,000	Siberian Elm
134	3	15	5	3	80	Field	"	50	Walker Poplar
134	3	15	5	3	80	Field	"	300	Acute Willow
134	3	15	5	3	80	Field	"	50	Col. Spruce
134	3	15	5	3	80	Field	"	50	White Spruce
134	3	15	5	3	80	Field	"	50	Scots Pine
134	2	13	6	3	80	Field/Farm	1	500	Ash
134	2	13	6	3	80	Field/Farm	"	3,000	Caragana
251	5	28	25	2	80	Field	1.5	1,175	Siberian Elm
251	5	28	25	2	80	Field	"	50	Walker Poplar
251	5	28	25	2	80	Field	"	75	Villosa Lilac
251	5	28	25	2	80	Field	"	70	Col. Spruce
318	35	31	17	3	80	Road	0.25	1,325	Caragana
318	35	31	17	3	80	Road	"	160	Col. Spruce
345	25	35	8	3	80	Field	0.5	3,000	Caragana
345	25	35	8	3	80	Field	"	25	Villosa Lilac
345	25	35	8	3	80	Field	"	50	Col. Spruce
345	25	35	8	3	80	Field	"	50	Scots Pine
349	32	35	18	3	80	Field	3.5	475	Ash
349	32	35	18	3	80	Field	"	21,800	Caragana
72	14	7	30	2	79	Combined	3	275	Ash
72	14	7	30	2	79	Combined	"	275	Siberian Elm
72	14	7	30	2	79	Combined	"	15,600	Caragana
72	14	7	30	2	79	Combined	"	700	Villosa Lilac
72	14	7	30	2	79	Combined	"	350	Col. Spruce
189	23	20	22	2	79	Field	0.5	200	American Elm
189	23	20	22	2	79	Field	"	1,500	Caragana
189	23	20	22	2	79	Field	"	100	Walker Poplar
189	23	20	22	2	79	Field	"	100	Villosa Lilac
189	23	20	22	2	79	Field	"	25	Chokecherry
189	23	20	22	2	79	Field	"	40	Col. Spruce
189	23	20	22	2	79	Field	"	40	Scots Pine

the user to the potential for inherent error within the digital database. More importantly, it also permits inferences to be made when key information (planting distance, shelter type, etc.) is missing.

A necessary requirement of this research is to obtain a measure of shelterbelt density per unit area. This can be accomplished easily using air photos or field surveys. However, interpretation is required when using the PFRA distribution records. The main variable recorded in each individual PFRA file is the number of trees of each particular species shipped for each order. The number of trees used for a set of shelterbelts is a useful indication of windbreak quantity, but comparison between tree counts and the linear dimensions derived from field-surveyed or remotely-sensed studies can be problematic.

The principal unit of shelterbelt measurement is linear distance, commonly expressed in terms of mileage (corresponding to the land survey systems of Canada and the United States). In several of the shelterbelt application records, the mileage value of a proposed field or road shelter is provided; for example, "¼ mi.". Unfortunately, many entries, particularly those from the early half of the study period, do not have distances annotated. Because plant spacing differs widely depending on the selected species, using tree counts to quantify shelterbelt density was considered inadequate. For example, in terms of shelter coverage, 1,000 caragana in Township 'A' does not equal 1,000 Green Ash in Township 'B'. The latter represents a much greater shelterbelt density due to the wider plant spacing. One method of converting tree counts to a linear measure is simply to multiply the number of trees of a particular species by a 'standard planting distance' (the linear spacing between seedlings within a shelterbelt row). Plant spacing distances are prescribed by the PFRA as being optimal for shelterbelt development. For example, in field applications, densely growing caragana has traditionally been planted at one foot intervals, while larger growing species, such as green ash, were typically planted every six feet. When the number of trees per species is multiplied by the planting distance, a value representing shelterbelt length per species is obtained. A sum of each such measure for each of the applicant's requested species, divided by 5,280 (feet per statute mile), provides the total calculated planting distance, in miles, for the applicant's land that year.* It is this figure that is mapped.

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* The linear unit 'miles' has been used in place of the metric standard 'kilometres' in order to maintain uniformity with the existing land survey system upon which the areal units (section/township) are based.

Although recommended planting distances have remained fairly consistent over the fifty-year study period, periodic modifications of the prescribed plant spacing distances have been noted. Based on the findings of long term shelterbelt growth and health research, recommended spacing for certain species has occasionally increased. Documentation of recommended planting distances is not obtainable for most of the study period. Therefore, all calculated distances were verified for each year of the data set by comparing the number of trees supplied to the applicant's stated shelterbelt distance, (where available in the record). A list of shelterbelt species, their standard planting distances used in calculations, and explanatory plant spacing statistics may be consulted in Appendix B. It should be noted that inferred plant spacing is a product of the 'number' and 'species' database parameters. Functions of shelterbelt 'type' were not compensated for. For example, no allowance was made for any potential difference in plant spacing for a 'field', as opposed to a 'road', shelter. The effect of this exclusion on the distribution mapping is considered to be negligible.

The principal mapping unit, calculated shelterbelt linear mileage, is not intended to infer actual measurable mileage on the ground. Shelter design varies depending on the requirements of each individual application. Therefore, despite the fact that the calculated linear distances referred to in this document are useful for comparative purposes, they more accurately indicate shelterbelt *density* per unit area, rather than actual distances. The potential for differences between calculated and actual mileage is apparent in the case studies of Chapter 6.

Chapter 3
Study Background

3.1 The Study Area

3.1.1 Area location

The research investigates shelterbelt distribution for all arable portions of Saskatchewan. This area can be generally defined as stretching from the Manitoba boundary in the east to the Alberta border in the west, from the 49^{th} parallel in the south, northwards to a line crossing between Hudson Bay (52°52'N, 102°23'W) and Meadow Lake (54°07'N, 108°28'W). In terms of township (Twp.) and range (Rge.), the study area spans from Twp.1 to approximately Twp.60, and from Rge.30, First Meridian West (W.1) to Rge.30, W.3 (see Figures 3.1.1 and 3.1.2).

3.1.2 Climate

The climatic characteristics of southern Saskatchewan are a direct determinant of shelterbelt use. Shelterbelts act as micro-climate modification mechanisms and, as such, their usefulness largely depends upon *local* conditions.

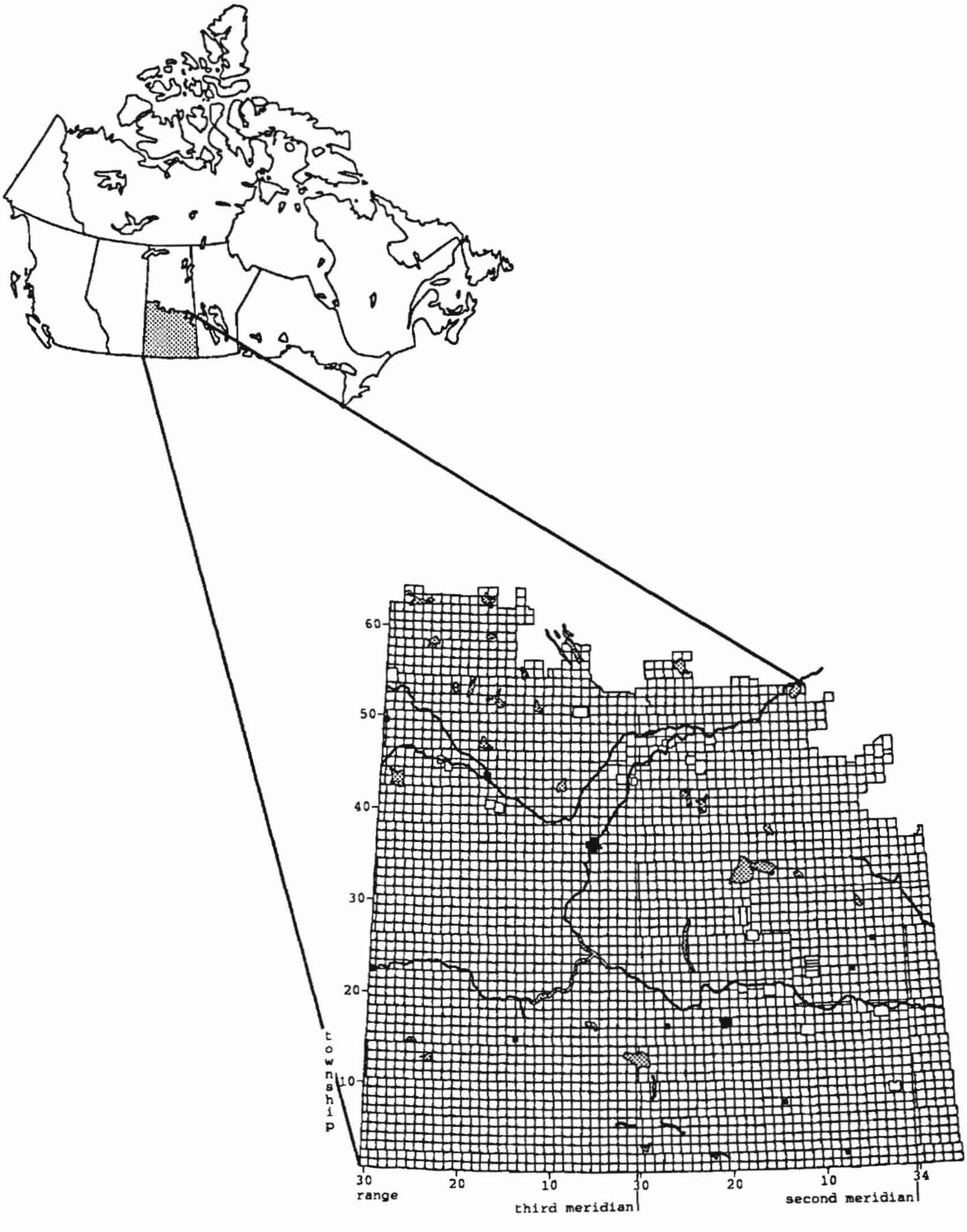


Figure 3.1.1: The study area (showing townships).

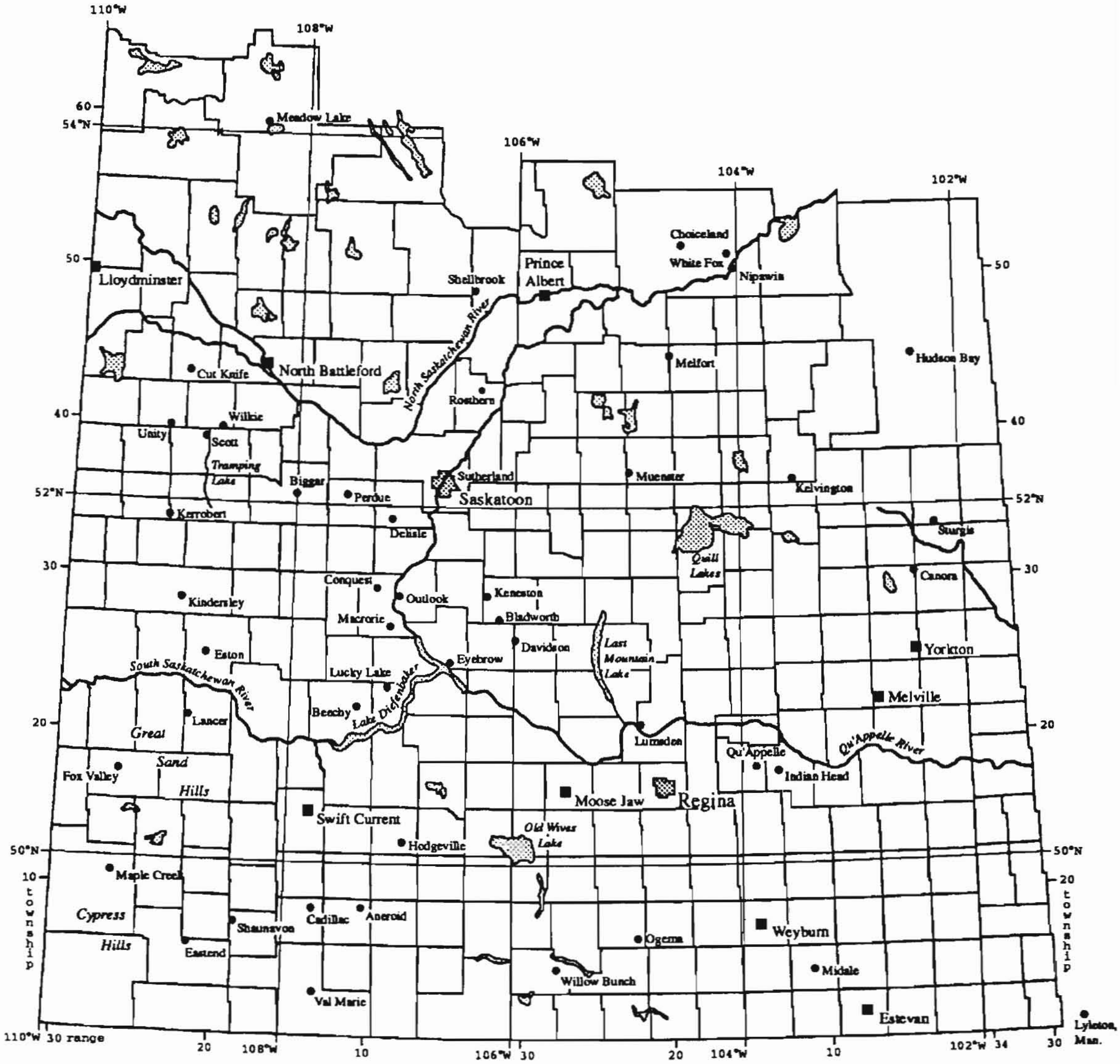


Figure 3.1.2 Places referred to in the text (with RM boundaries).

Much of the southwestern one-third of the study area, excluding the Cypress Hills, is defined as 'semiarid' in the Thornthwaite system and 'cold steppe' under the Köppen classification (Köppen—BSk). Most of the north-east portion of the study area, is classified as 'dry subhumid' (Thornthwaite) or alternatively, 'snowy forest-warm summer' (Köppen—Dfb). Both the semi-arid and subhumid climate zones feature warm summers and cold winters. Normal (1961-90) July daily mean temperatures range from 16.5°C in the Meadow Lake district to 20°C near Estevan. Winters are coldest in the northeastern portion of the study area. Normal January daily means range from -20°C in the Prince Albert-Choiceland area, to -11°C at Maple Creek in the province's south-west. Most of the study area experiences 1450 to 1850 degree days above 5°C and 90 to 130 frost-free days yearly. A long-term summary of climate information for a selection of sites may be consulted in Appendix C.

Annual precipitation ranges from little more than 300 mm in the southwest, to approximately 450 mm in the northeast. Generally, less moisture is available in the steppe zone. The south-central (Lake Diefenbaker) area is comparatively dry, with annual precipitation totaling less than 350 mm in most places. Throughout the study area, the bulk of precipitation falls as rain during the early summer. Total precipitation can vary greatly from year to year, causing large shifts in the dry-humid boundary that defines the climate zones (Figure 3.1.3).

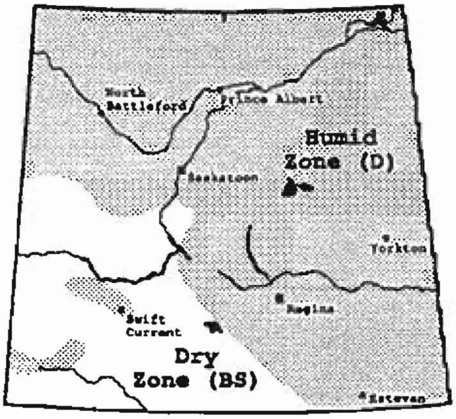


Figure 3.1.3: Average boundary between dry and humid climate zones, 1931-60.
(after Fung, 1999)

Agriculturally-destructive drought frequently visits southern Saskatchewan. It has occurred in all decades of the study period except the 1950s. As an illustration of its potential pervasiveness, over just two decades, between 1970 and 1990, drought affecting cereal crops hit agricultural Saskatchewan in 1974, 1979-80, and 1984-85. Over the same period, hydrological droughts occurred in 1977, 1981, and 1984, while droughts in 1980 and 1984-85 were notable for damaging forage crops (Frechette, 1990). An especially destructive drought, beginning in the autumn of 1987, and peaking in the spring of 1988, severely affected agriculture. Forage production was particularly vulnerable and crop returns were 50% of five-year average.

3.1.3 Soils

Soils in Saskatchewan have been organized into spatial zones based on the Canadian System of Soil Classification. The zones are generally defined by the colour of the surface material; a reflection of the amount of organic matter, which is itself influenced by climate and vegetation (Acton *et al.*, 1998). 'Brown' to 'dark brown' to 'black' Chernozemic soils dominate the study area. The lighter soils are found in the southern dry grass-land portions of the province, with a gradation to darker soils in the more northerly moist grassland and fescue-dominated aspen parkland. Dark grey Chernozemic and grey Luvisolic soils have formed along the northern fringes of the study area, reflecting the transition from grassland to forest. Regosols are present in many areas, including river valleys, where vegetation stabilization is poor. Distinct Solonetzic zones have also been mapped (see Figure 3.1.4). The soil zones provide a generalized overview of *natural*

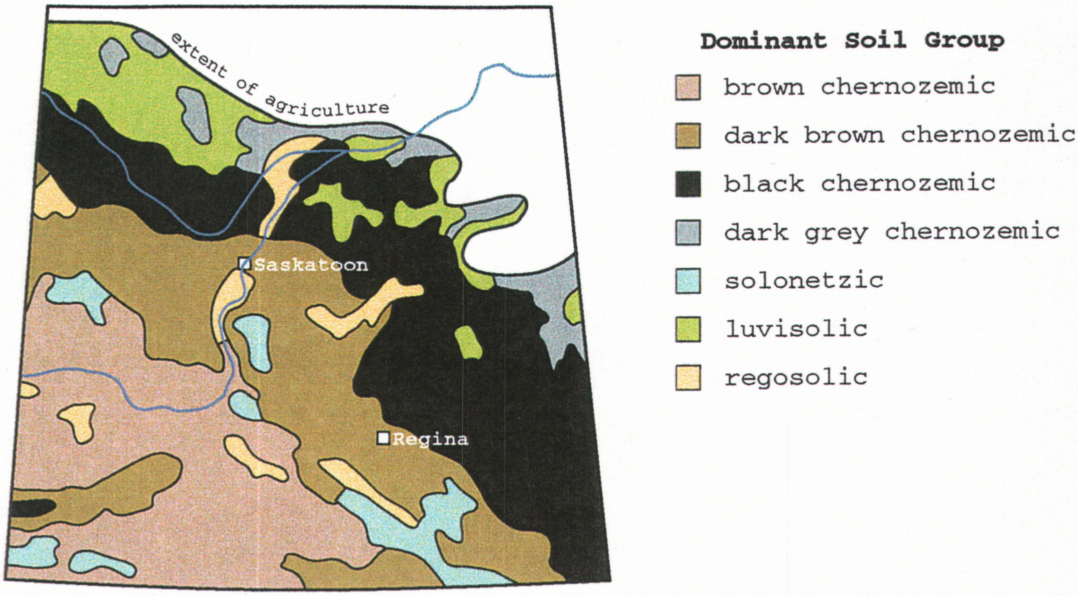


Figure 3.1.4: Generalized major soil groups for agricultural-Saskatchewan.
(after Bootsma *et al.*, 1992a)

distribution. Soils are altered by cultivation, whereby exposure leads to the leaching of organic and mineral materials, eventually resulting in type metamorphosis.

The principal reason for establishing field shelterbelts is to prevent soil erosion by wind. Among other factors, the erodibility of a soil depends upon its texture and moisture content, as well as its organic composition. Southern Saskatchewan soils and surficial deposits are represented in every texture class, from clay to gravel, depending upon local geological and geomorphic history. Moisture content is a function of several factors including climate, topography, surficial geology, and agriculture, and as such, is subject to great temporal and spatial variation. Organic composition is, in most places, determined entirely by agricultural practices. Some excessively-tilled areas have lost a substantial amount of organic matter. Several variables have been combined by Agriculture Canada (1987) for the purpose of calculating 'Wind Erosion Risk'. The results have been mapped for southern Saskatchewan (Figure 3.1.5), and a description of the calculations used is provided in Appendix D.

3.1.4 Ecology

Ecological descriptions are introduced in Chapter 6 to illustrate the degree to which various areas will naturally support cultivation. Eco-classification identifies marginal lands which may be at greater risk of eolian erosion. Additionally, shelterbelt tree species have specific habitat requirements, which may or may not be met within a certain location. A district's natural ecological character can indicate the suitability of a given shelterbelt species.

The majority of agro-Saskatchewan exists within one of four main ecoregions within the Acton *et al.* (1998) classification system. These transition from south to north from 'mixed grassland', through 'moist mixed grassland',

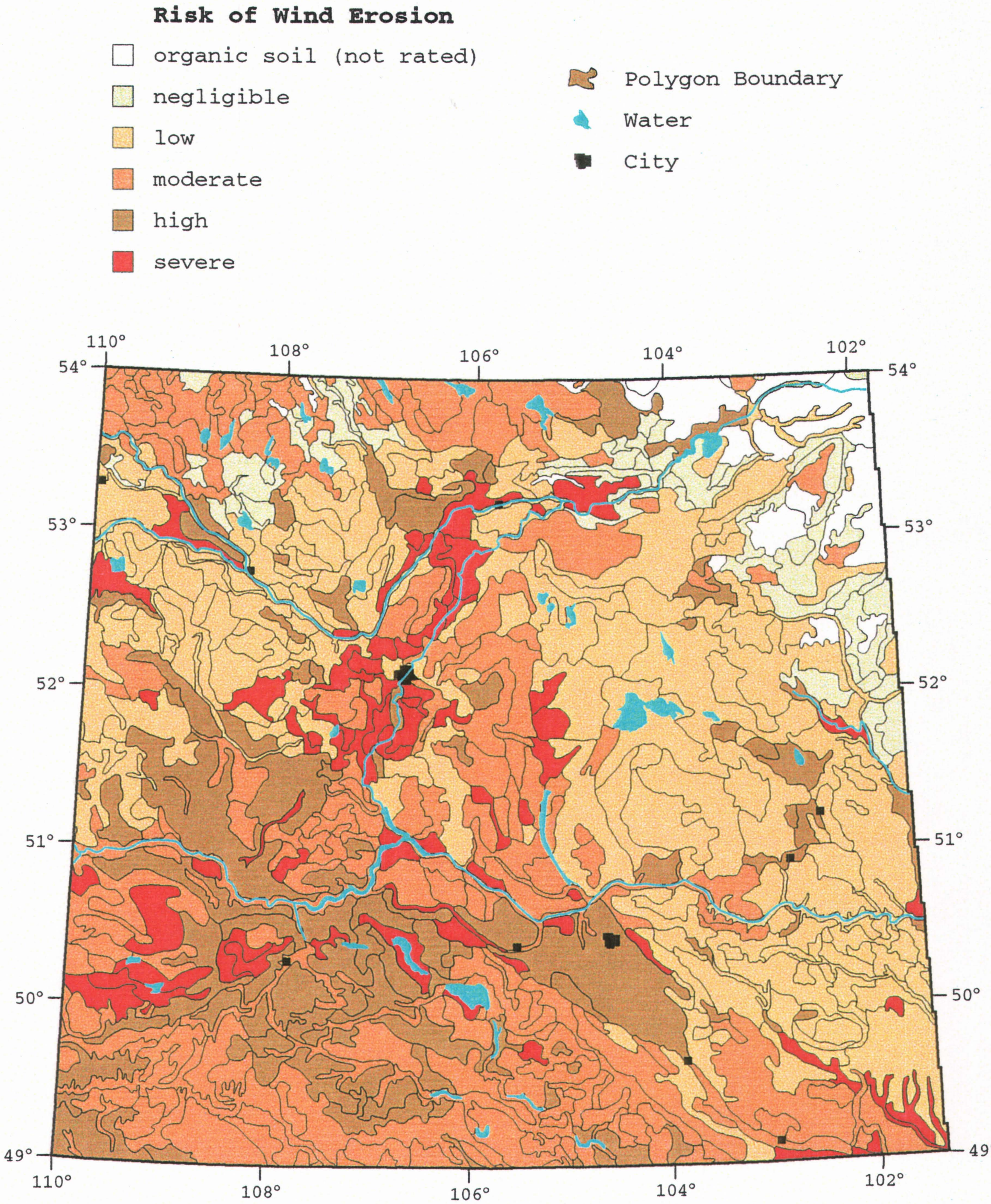


Figure 3.1.5: Wind erosion risk zones for southern Saskatchewan (based on soil survey polygons). (after Agriculture Canada, 1987)

and 'aspen parkland' to 'boreal transition' (Figure 3.1.6).

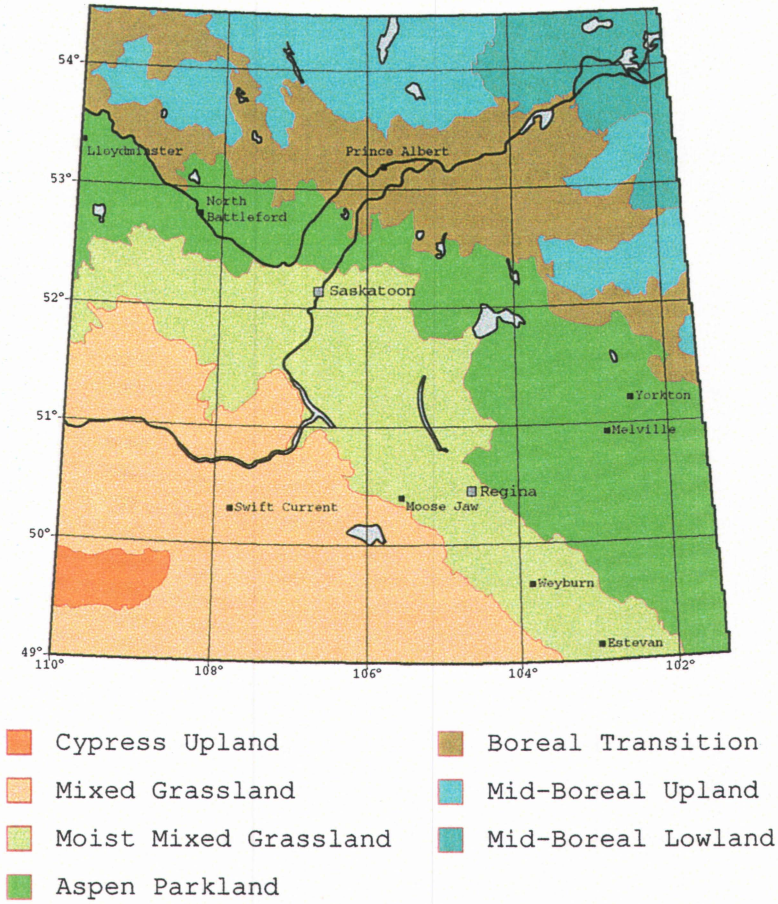
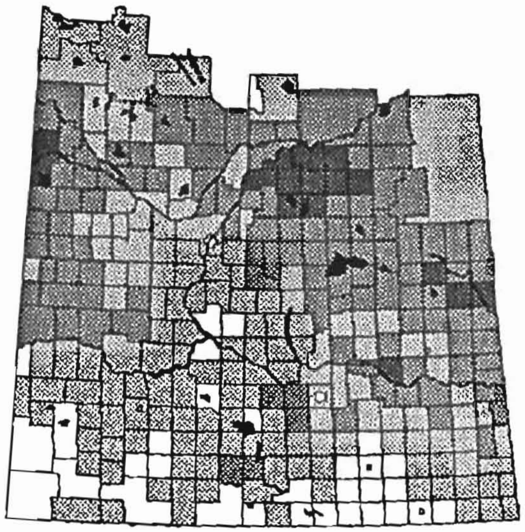


Figure 3.1.6: Saskatchewan ecoregions. (after Padbury and Acton, 1994)

3.1.5 Agriculture

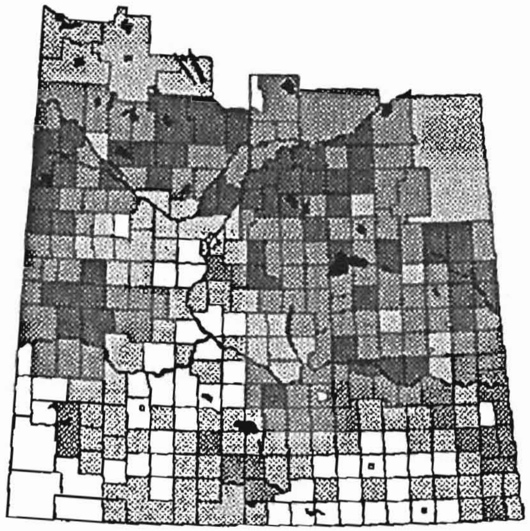
Nearly the entire study area is farmed. Approximately two-thirds of this is cultivated for cereal and forage production, with the remainder either improved pasture or rangeland. Several grain and oilseed crops including wheat, oats, rye, barley, canola, flax are grown. Productivity varies spatially, with the highest returns realized near Melfort (Figure 3.1.7). The south-west, south-central, and Lake Diefenbaker areas are the least productive. On average, each seeded hectare of Saskatchewan cropland is capable of producing 58 bushels of spring wheat annually. Grazing land is scattered throughout the study area, but is most concentrated in the south-west. Mixed farming occurs in the more humid areas to the north and east.

Various agricultural systems have traditionally been employed in Saskatchewan. For the most part, agriculture over the past fifty years is characterized by large farms practicing highly mechanized, mono-crop cultivation. Farm size has continually increased over this period. Some of the more intensive farming practices have historically exacerbated soil loss and moisture deficit problems, and are therefore a major factor in field shelterbelt use. For example, summer fallowing involving heavy tillage, (a traditional method of moisture conservation and weed control), has caused substantial soil erosion, soil salinization, and several other problems in many parts of the province. Recently, many research and education initiatives exploring 'sustainable' farming methods have received government and private support, initiating an



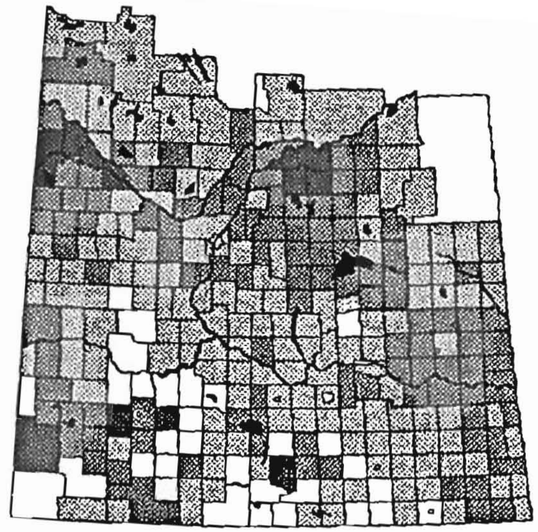
Average Yield
(bushels per hectare)
0-49 | 60-69
50-59 | 70+

Spring Wheat



Average Yield
(bushels per hectare)
0-79 | 90-99
80-89 | 100+

Barley



Average Yield
(bushels per hectare)
0-39 | 50-59
40-49 | 60+

Canola

Figure 3.1.7: Average crop yields by RM, 1949-98.
(based on SAF data)

evolution in agricultural practices. Conservation fallowing (including chemical-fallowing and reduced- or zero-tillage), water management, farm diversification, and several other practices designed to lessen the impact of agriculture on the land, are now gaining greater acceptance. Selected Saskatchewan agricultural statistics are illustrated in Appendix E

3.1.6 Social-economic character

Cultural and economic factors are also important determinants of field shelterbelt use. Saskatchewan producers are predominately of European origin and many traditional farming practices and philosophies can be traced to ancestral agrarian roots in Britain, Russia, the Ukraine and several other homelands. Much of the agricultural settlement occurred in a number of 'ethnic' communities and many of these, for example, the Mennonite communities near Swift Current, have retained distinctive cultural characters (Figure 3.1.8).

A substantial portion of Saskatchewan's economy is derived from agriculture, although the share has steadily decreased over the study period. Economic input is realized through farming, support services and manufacturing, transportation, processing, marketing and financing.

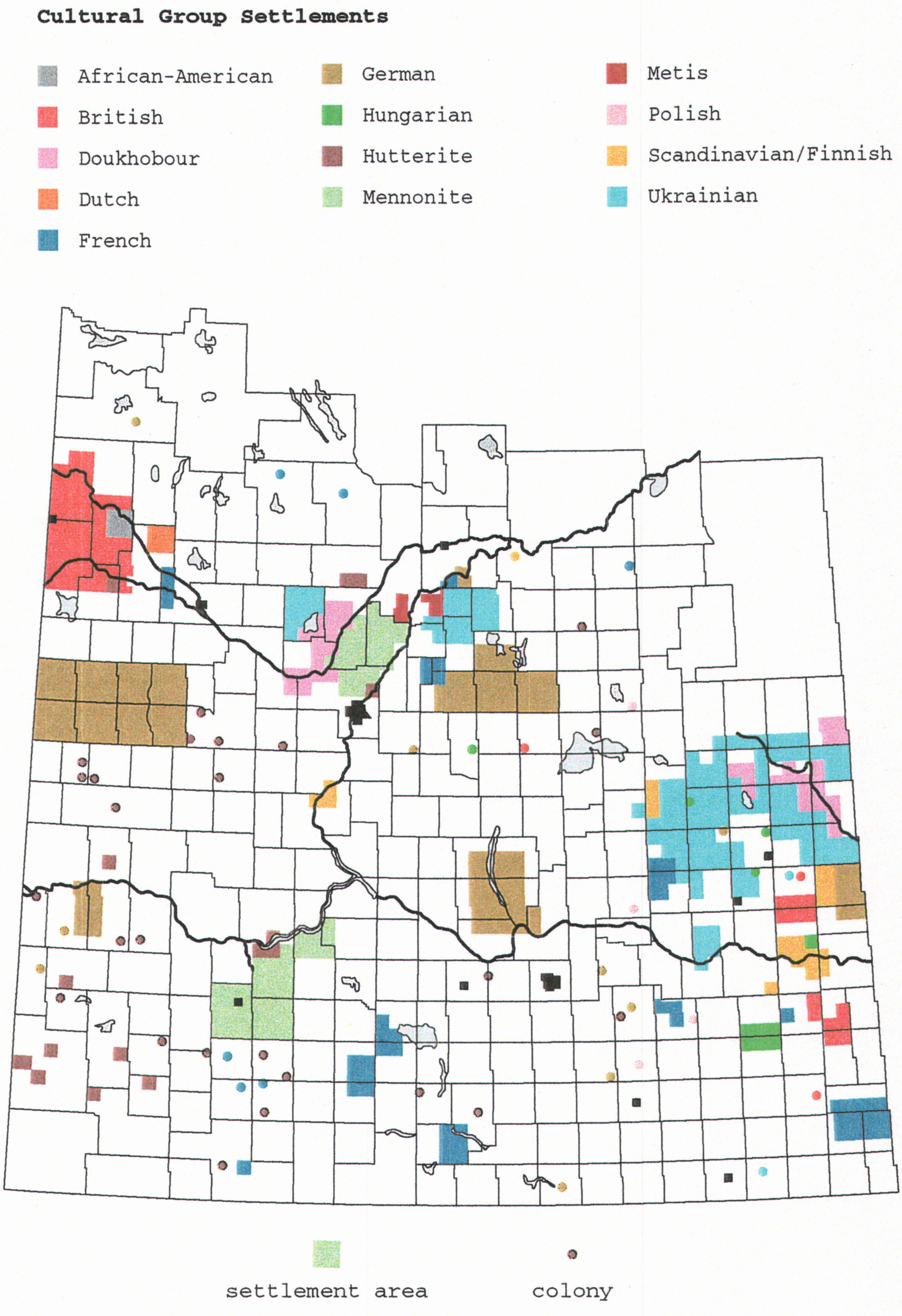


Figure 3.1.8: Saskatchewan major ethno-cultural group settlements, 1870-1999. (after Fung, 1999)

Individual producers are at the core of the agro-economy, and it is their personal financial state of being that influences shelterbelt use.

Farm income, which depends on market-driven commodity payments, tends to fluctuate. However, income variation has been dampened over the past twenty-five years as 'off-farm' employment wages and other remuneration, such as investment income and non-farm transfer payments (pensions, family allowance) have become the primary source of earnings. Additionally, numerous federal, provincial, and inter-governmental financial assistance measures have been available throughout the study period and have undoubtedly contributed to farm income stability. Example programs include the Western Grain Stabilization Act (WGSA), the Net Income Stabilization Act (NISA) and Economic Regional Development Agreements (ERDA). In many cases, these and additional initiatives, such as the Saskatchewan Crop Insurance Act (CI) and the Farm Credit Corporation (FCC), have reduced financial burdens resulting from production and market deviations. For example, during the mid-1980s drought, CI and the WGSA payments accounted for 85% of total crop income in some places (Agriculture Canada, 1986).

3.2 Pre-study Period Origins of Shelterbelt Use

3.2.1 Historical contexts

Several historical factors are the basis of shelterbelt distribution patterns now observed in Saskatchewan. These factors are contextual in nature and are included here to supplement the determinants described in section 3.1. Four primary pre-study period contextual influences are identified: meteorological hazard events, economic history, social-ethnic predisposition to use, and, past farm practice and philosophy.

From the beginnings of agrarian effort in the late 19th century, both meteorological (below normal precipitation), and hydrological (depleted groundwater) droughts negatively affected agricultural production. During the pre-study period, severe drought has been documented as causing loss to Saskatchewan farms in the late 1880s to early 1890s, as well as in 1910, 1914, 1917-20, 1924, 1929 and throughout the 1930s (Frechette, 1990). Of these, the 1930s disaster has undoubtedly had the greatest influence on shelterbelt use. It was during this period that the PFRA was initiated and field shelterbelt research began in earnest. Meteorologically, the droughts of the 'thirties' were similar to those of the 1980s, but due to differing prevailing economic conditions, they are typically perceived as being more intensive. Historically, agricultural drought (a combination of meteorological and hydrological drought) necessitated the implementation of various response mechanisms to reduce the impact of soil moisture deficit and wind erosion. Field shelterbelts were one such response, and, due to the severity of the historic droughts, were probably investigated more thoroughly during the pre-study period (particularly the 1930s) than they might otherwise have been.

Closely coupled to the droughts were periodic intensive dust storms. Dust storms are a product of meteorological, edaphic and human use conditions. Wheaton and Chakravarti (1987) have determined that, on average, dust storms occur one to four times per year in agricultural Saskatchewan. Historical dust storms undoubtedly provoked a forceful perception of disaster, primarily because of the powerful visual image of gloom they evoked. The degree to which dust storms influenced contemporary thought is easily observed through the widely used descriptive phrases "dirty thirties" and "dustbowl". Although the former term undoubtedly had additional social-political-economic connotations, the portrayal is lucid. Despite being relatively uncommon, dust storms can quite easily be connected in the mind with the soil deflation widely observed on unprotected fields and almost certainly had a great positive influence on anyone considering field shelterbelts (Figure 3.2.1).

Economic fluctuation undoubtedly also influenced a perception of 'disaster' necessitating response. For the pre-study period, this is most easily linked to farm income problems, which are related to commodity price variation.

Figure 3.2.1: Soil deflation and drifting near Lyleton, Manitoba, 1934. Note the exposed elevation marker. The entire soil profile has been removed.
(photo by J.H. Ellis, courtesy of University of Manitoba Archives: Ellis Collection, PC.19)

From 1906 to 1919, the average indexed price paid for wheat rose steadily from $0.77 per bushel to $2.32 allowing a steady increase in the standard of living (Dehm, 1969). Newly found prosperity encouraged agricultural settlement well into marginal lands. Following a large drop in early 1920s' grain prices, the provincial government took control of marginal areas and many of the landowners migrated to northern agricultural fringe areas with public assistance. After 1924, grain prices rebounded, mechanization allowed much farmland to be converted from forage to cash crops (as the number of horses and oxen requiring feed declined), and relative affluence was the result.

Late 1920s profits were forgotten in 1930 when grain prices crashed. The drought and accompanying insect infestations of the mid 1930s ultimately drove production to as low as 6.5 bushels per hectare in 1937. Soil erosion severely affected the recently broken marginal areas and most producers suffered financial difficulties. Federal and provincial aid and relief pay-outs for 1931-37 totaled $84.2 million and total farm debt surpassed $500 million by 1936. Primarily driven by soil conservation concerns, the PFRA and the Provincial Land Utilization Act were proclaimed in 1935 and 1937, respectively. After 1939, grain prices rebounded and production remained average for the rest of the 1940s. However, the lessons of the 1930s had been learned and, by 1949, a number of conservation practices, including shelterbelts, had been widely adopted as a defence against future economic threats.

Agro-economics are highly dependent upon farm production, which is itself influenced by agricultural practice. The settlement history of Saskatchewan and the agrarian philosophies of the settlers has had an identifiable, although not easily quantified, influence on shelterbelt adoption. When European farm settlers first arrived on the Canadian prairies in large numbers, the idea of planting shelterbelts was already well-known in Europe and North America. In Great Britain, the country from which many of the early agricultural settlers had arrived, shelterbelts had become widespread and well-established by the mid-eighteenth century (Caborn, 1965). This introduced a tradition of tree planting to the Canadian plains, ensuring an entrenching, and then continuation of the practice. As suggested by the common 19th century American term 'windbreak', (equivalent to 'shelterbelt'), the first trees were obviously planted to provide a barrier to wind. However, Rees (1988) believes early tree-planting initiated originally from the beginnings of European prairie settlement mainly for social-cultural, rather than local climate modification reasons. Europeans are presumed to have held a high aesthetic regard for woodlands and forests, believing open prairie to be "a landscape without validity" (Rees, 1988).

Towards the mid-19th century, contemporary scientific philosophy advocated tree planting. Climatic modification borne out of artificial tree stands was a popular notion amongst American, and later Canadian, academics and planners. Many at the time believed trees contributed to increased local rainfall, caused lower summer and higher winter temperatures, and prevented hail formation. It was suspected that the prevailing hot and dry climatic nature of the North American plains was due to a dearth of trees. This unfortunate confusion of cause and effect was later corrected, but during the late 1800s, tree planting continued to be heavily promoted for its perceived *macro*-climatic benefits. Climate-modification reasoning was advanced to provide justifiable support for the less practical cultural and aesthetic promotion of the costly and difficult practice of planting and maintaining trees in an environment unsuited to them (Rees, 1988).

Eventually, as greater understanding of shelterbelt dynamics was gradually achieved, the climate—modification reasons for planting included more valid arguments that reflected consideration of micro-climatic scales. However, cultural attraction to trees remained very powerful. Circa 1940, Norman M. Ross, head of the Indian Head Dominion Forest Nursery Station's tree-planting division is recorded as stating the greatest value of trees was not their utility, but their "aesthetic" quality (Ross, c1940).

Finally, agricultural practice and policy also provide important historical contexts for field shelter adoption. The connection is through the fact that standard farming systems utilized by early producers contributed directly to a pervasive eolian erosion problem affecting much of agricultural Saskatchewan. The root of the problem was negligence on the part of contemporary agricultural experts (Jones, 1985), and the widespread cultivation of marginal lands that followed a highly successful harvest in 1915 (Anderson, 1975). According to Jones, the early 20th century agricultural community failed to adequately adapt to the often specialized requirements of dryland farming. At the end of the 19th century, the highly influential Ontario Agriculture College (OAC) adhered to a "rural theology" of 'technology conquering the elements' and a "rural ideology", whereby it was the "duty of man" to occupy nature (Jones, 1985). This ideology, unfortunately, was responsible for the circulation of erroneous information to turn-of-the-century prairie farmers. For example, OAC graduate Angus MacKay, (appointed superintendent of Indian Head Experimental Farm in 1888), strenuously promoted a potentially harmful farm management system centered on intensive tillage practices (cited in Jones, 1985).

Tillage has always been fundamental to farming in North America and Europe. *Excessive* tilling probably began with the introduction of mechanical traction devices. Steam tractors were available as early as the 1870s but were not widely used due to high purchase and operation cost. Mechanized farm equipment was greatly improved between 1914 and 1918. However, even with the wartime labour shortage, farmers were typically not willing to pay the equivalent cost of five to seven work horses to purchase a tractor at a time when fuel was scarce (Thompson, 1978). Widespread use of the lightweight tractor finally occurred in the early 1920s when economic conditions allowed increased investment in implements (Murchie *et al.*, 1936).

Initially, much of the tillage-based farming advice advocated by a number of influential 'experts' in Canada and the United States seemed sensible in the interests of moisture conservation. Unfortunately, most prescribed practices also exposed topsoil, rendering it vulnerable to wind erosion. Summer fallowing was particularly favoured by the experts, although individual farmers began to doubt the benefits after serious dust storms of the early 1920s carried off much of the soil in many areas (Figure 3.2.2).

Farm experts considered farm failure the result of poor technique rather than a product of adverse environmental conditions. W.R. Motherwell, a long-time provincial, and later federal agriculture minister,

Figure 3.2.2: Dust storm, 1937. The land on the photo right is vegetated and is not being eroded. The severely drifting land on the left is tilled summerfallow.
(photo by J.H. Ellis, courtesy of University of Manitoba Archives: Ellis Collection, PC.19)

declared that "drought or no drought, success or non-success is chiefly, if not entirely, due to straight good or bad farming" (cited in Jones, 1985). Often, many producers obediently practicing 'good farming' were doomed to disaster. Not all research agrees with this conclusion, however. Spector (1983) maintains that the techniques advocated by the experts "revolutionized" prairie farming and, in fact, allowed it to flourish. Ultimately, by the 1920s, many farmers understood the need for balance between moisture retention and soil loss and began to develop innovative systems best suited to their local conditions. 'Ploughless' farming (low tillage) was one such solution. This and other farming modifications allowed many producers to be better placed when disaster hit again in the 1930s.

As a footnote, W.C Palmer, professor at the North Dakota Agricultural College, pronounced in 1912 (cited in Jones, 1985), his *'Ten Commandments of the Dry Farmer'*. Following typical admonishments to plough deeply, keep surface soil loose, summerfallow, and so on, Commandment 'Number 10' stated: "Thou shalt Plant Trees".

3.2.2 Canadian government prairie tree planting policy

According to Howe (1986), trees were used for shelter on the earliest prairie settlements. Shelterbelts were attempted using trees transplanted from nearby river-banks, or, in some cases, plants imported from eastern Canada or the United States. These efforts failed to take root, principally because of the poor hardiness of the stock and improper planting site preparation. The federal government, recognizing the tree propagation problems encountered by farmers, became involved in an effort to increase the success of shelterbelts.

The practice of planting trees for shelter was given official recognition and assistance in 1886 with parliament's passing of a resolution proposing establishment of several agricultural experimental stations. Tree research was of particular interest to the government (Anstey, 1986). Deliberately planted trees were favoured then, mainly as a maintainable timber supply, but the shelter benefits, and the then-popular notion of macro-climate modification, were also considered important. Undoubtedly, the late 19^{th} century United States policy of granting land solely on the basis that trees would be planted raised attention in Ottawa.

When development of the first federal agricultural experimental site, the Central Experimental Farm, was initiated in 1887 at Nepean, Ontario, shelterbelt establishment was included in the first year of construction. By the mid-1890s, all experimental stations including those at Indian Head and Brandon, Manitoba maintained a stock of trees for distribution to the public (Anstey, 1986). According to Howe (1986), from 1888 to 1899, the Central Experimental Farm distributed 65,000 trees and shrubs to the experimental stations at Indian Head and Brandon as well as 560,000 seedlings and 900 pounds of seed directly to farmers. Throughout the 1890s, the experimental stations gradually took over the distribution efforts from the central farm at Ottawa.

As the scope of the official programs grew, government involvement was further organized. The Forestry Branch of the Department of the Interior was responsible for initiating the first broad co-operative tree planting system in 1901. Under this program, farms, municipalities, and corporate landholders were eligible to receive trees free of charge upon inspection and approval of the proposed planting site, and its preparation by Forestry Branch staff. By 1902, the tree nursery at Indian Head had been made permanent and a similar effort was initiated at Sutherland in 1913. Howe (1986) provides the operational objectives of the Indian Head Forestry Nursery Station as follows:

1) Not only that the trees shall be grown in large quantities for distribution to the settlers throughout the treeless plains, but also the station shall be a model forestry farm where visitors will be able to see the possibilities of growing a variety of trees.

2) To do some experimental work in the growing of certain varieties of introduced species of forest trees from other parts of the world possessing a climate similar to our own.

3) To gather statistics here of the relatively yearly increase in the growth of different varieties under cultivation and other information of great value to the people of the prairie region.

Furthermore, station staff were expected to provide advice to farmers on planting technique, the best location for planting, and on the preferred methods of maintaining newly established trees. By 1906, the Indian Head nursery had replaced the experimental farms as the sole agent of tree distribution and production. Sutherland, established to supplement the station at Indian Head, remained in operation until consolidation with the latter in 1966.

The scale of the official involvement is evident from the number of trees distributed. From 1892 to 1998, it is estimated that more than one half billion seedlings were delivered by the Indian Head, Brandon and Sutherland nurseries to prairie farms (from Howe, 1986 and figures calculated from PFRA data).

3.2.3 Field shelterbelt policy application

From the beginning of the Forestry Nursery Stations' operations, trees were supplied for various purposes including field shelterbelts. However, Howe (1986) suggests that nearly all plantings up to 1930 were for farm shelters. There is evidence of investigation into the potential of field shelterbelts immediately following a drought in 1917-18, but this was forgotten with a return to favourable conditions over the next decade (Ross, c.1938). It was the severe drought conditions of the 1930s that ultimately caused increased use of trees in field applications. Howe (1986) states that from 1935 tree plantings "became an integral part of soil conservation as spelled out in the PFRA mandate". Despite the original government interest in aesthetics and the potential use of shelterbelts as a ready timber supply, and its continued promotion of those benefits, by the late 1940s, "protection" was considered the main function (Edwards, 1948).

To explore and develop the concept of field shelter, PFRA 'Shelterbelt Associations' located at Conquest and Aneroid, Saskatchewan; Lyleton, Manitoba; and Porter Lake, Alberta, as well as seventy-nine 'Illustration and Experimental Sub-stations' were initiated. According to

Howe, 2,483 kilometres of field shelterbelts were planted in conjunction with these projects (Figure 3.2.3). These initiatives were designed primarily to test the effectiveness of shelterbelts in controlling soil drift (Anderson, 1975). From 1935 to 1939, grants were paid to farmers to assist in planting and maintaining field shelterbelts.

Following the 1930s, in response to difficulties (especially pathological ones) encountered due to the recent widespread promotion of shelterbelts, the

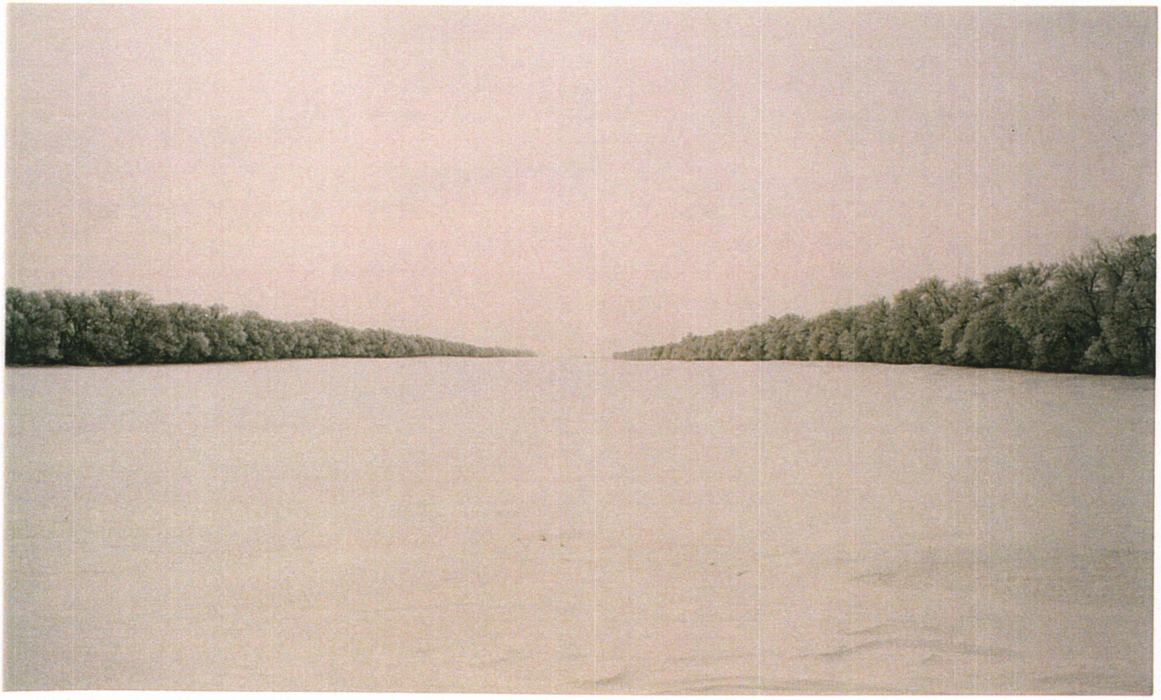


Figure 3.2.3: Mature American elm shelterbelts at Conquest in March, 1999.

Experimental Farms Branch initiated further scientific evaluation and experimentation programs. By 1959, farmers had been made responsible for all shipping costs involved in receiving trees and, in 1960, payments for the maintenance of established plants ceased. After that, the primary impetus for establishing field windbreaks shifted from governmental agencies to individuals, although several smaller government-sponsored projects have continued through to the present. In 1963, the PFRA assumed control of the nurseries from the Experimental Farms Branch, and by 1968, the first trees were supplied for wildlife, soil reclamation and prairie parks applications.

Chapter 4
Principles of Shelterbelts

4.1 Planting Purposes

Shelterbelts have been planted in Saskatchewan for a number of purposes. Several "shelter type names" are found within the PFRA archive records, notably: 'Farm', 'Field', 'Road', 'Wildlife', and 'Agroforestry'. Examples of other lesser or obsolete planting purposes are 'Rural Small Holding', 'Snow Trap', and 'Hedge'. The focus of this study is planting types primarily designed for agricultural enhancement, specifically: field and field-related ones. The major shelterbelt type names appearing in PFRA records or created for this thesis are listed in Tables 4.1.1 and 4.1.2. Planted shelterbelt mileage, by type, for each year in the record, is illustrated in Figure 4.1.1.

4.2 Shelterbelt Control of Wind Erosion

Control of soil loss due to eolian erosion is usually considered to be the most important function of field shelterbelts. Soil loss can cause significant changes to

Table 4.1.1: Major shelterbelt types mapped in chapter 5. Italicized types were created specially for this study and do not appear in PFRA data.

Shelterbelt Type	Primary Use	Notes
Field	mitigation of wind erosion and soil moisture problems	represent approximately one half of the total number of trees shipped by the PFRA since 1949
Road	provide protection to roads and drives (snow drifting management)	several also shelter fields adjacent to roadways
Combined	represents the PFRA "shelter type name": "Field/Road"	the dual purpose is specified
Snowtrap	planted where snow retention and distribution is the prime concern	obsolete terminology, now included in the Field category
Field/Farm	included because evidence suggests that trees were predominantly used for field purposes	
Road/Farm	included because evidence suggests that trees were predominantly used for road purposes	
Probable	type specially created in order to account for significant planting projects for which no purpose is stated in the records	criteria for classifying database record entries as Probable: 1) it contains an entry in the 'distance' field (for example, "½ mi.") 2) it represents at least one quarter mile of calculated distance. 3) for the year in question, the application order represents typical field shelterbelt species with numbers in usual proportions (for example, 5,300 Caragana)

Table 4.1.2: Major shelterbelt types not mapped.

Shelterbelt Type	Primary Use	Notes
Farm	provide protection to farm-yards, houses, barns, livestock enclosures, and other structures	account for approximately 90% of tree applications received by the PFRA each year
Wildlife	provide refuge, shelter, and a food source to avian and mammalian wildlife	typically feature large numbers of 'showy' or fruit-bearing trees of a variety of species
Dugout	provide snow capture for dugouts	
Agroforestry	self-explanatory	
Rural Small Holding	trees granted to holders of small land parcels (<40acres), primarily acreages and hobby farms	any RSH application identified as being intended for field shelter was included in the mapping

soil morphology. Based on the findings of a study of the 1930s prairie drought and wind erosion disaster, Ellis (1938) concluded that five types of soil "injury" occur as a result of eolian erosion:

1) a coarsening of soil texture in sandy loams and other soils from the loss of silt, clay, colloids and organic matter,

2) the development of 'blowouts' (deflation hollows) and possible destruction of the entire soil profile,

3) the migration of blown 'dirt' (clay, silt and organic particles),

4) the protracted truncation of fine textured soil profiles through a gradual "planing" (scouring or abrasion) process, and

5) the truncation of soil profiles on knolls and exposed slopes.

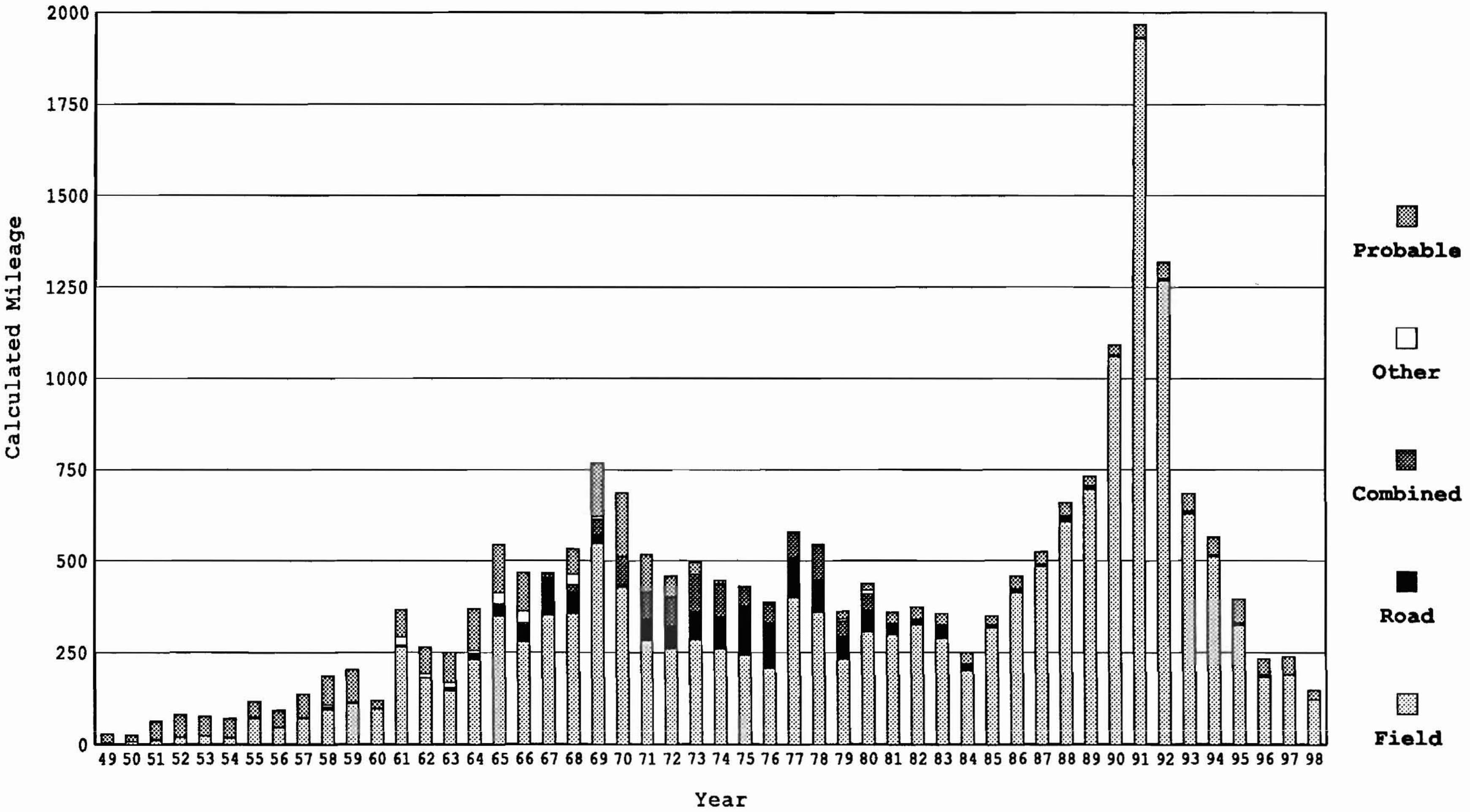


Figure 4.1.1: Shelter tree distribution by application type category, 1949-98.

Obviously, these effects are critical to agriculture as they can lead to a loss of soil fertility through physical, chemical and biological changes, crop plant abrasion, as well as damage to built structures. Since the 1930s, losses attributable to erosion in North America are measurable in the multi-billions of dollars (Colacicco *et al.*, 1989).

Wind erosion depends on two main phenomena, soil *erodibility* and wind *erosivity*. The former is a function of the physical properties of the exposed material at the ground surface. The erodibility of individual grains depends on their diameter, density, and shape (Wilson and Cooke, 1980). Generally, grains between 0.008 and 0.84 millimetres in diameter (silt to medium sand) may be moved by wind. A soil's structure also factors in its erodibility. For example, clayey materials often adhere to one another, forming clods which are less vulnerable to erosion compared to less cohesive compositions. Soil moisture is a prime determinant of soil structure, and organic content is also influential. Typically, higher levels of each equate to lower erodibility. Of course, these principles apply only to uncovered soils. The presence of vegetation greatly alters susceptibility to erosion. Roots improve soil cohesiveness while the above ground stems and leaves induce physical wind drag.

Wind erosivity is the quantifiable ability of moving air to entrain particles and is proportional to the cube of the average wind speed (Skidmore, 1988). Entrainment is primarily the result of wind surface drag, but is also influenced by air turbulence, aerodynamic uplift, and other factors. The threshold entrainment velocity required to initially move soil particles is higher than that required to sustain the movement. Lyles (1976) suggests that in agricultural situations, wind speeds less than 20 km/h are considered "non-erosive". A line of trees, planted with careful attention to spacing, presents a physical barrier to moving air, therefore preventing soil loss by reducing air velocity below the entrainment threshold. Thus, for soils with inherent high erodibility, a degree of artificial control may be introduced by mechanically reducing wind erosivity.

Tree or shrub shelterbelts affect local wind velocity by absorbing a portion of the wind's energy and deflecting the remainder. This tends to lessen wind speeds largely to the lee side of the shelter, but also, to a limited extent, on the windward side. This is accomplished by the tree barrier interrupting the uniform flow of unobstructed wind, resulting in turbulent motion which checks forward velocity (Caborn, 1965). The cushion of air built up on the windward side provides limited shelter on that face of the windbreak. The remainder of the flow passes over and through the shelterbelt, the proportion of each depending upon the density of the belt. In doing so, the air loses much of its energy. The ability of a windbreak to influence wind-flow depends on a number of variables including height, density, shape, orientation, and location.

The height of a shelterbelt is a product of three main factors: the age of the trees, the species chosen, and the local environmental suitability for that species. Height is a vital determinant of how effectively the shelterbelt reduces wind speed. Studies have demonstrated that the lateral extent of a shelterbelt's influence is generally six to ten times its height (Caborn, 1965). Shelterbelt spacing is therefore very important as shelterbelts have no cumulative effect. Wind speed returns to its unobstructed value beyond the six to ten times height limit. For Canadian prairie applications, the large scale agriculture commonly practiced would ideally require fairly high windbreaks. With a typical field covering a quarter section (0.65 km^2), eight parallel windbreaks, each consisting of trees ten metres in height, would theoretically be required to reduce winds across the entire field. Shorter trees would necessitate closer belt spacing, and in turn, would occupy an unacceptable amount of land, posing an obstruction to machinery. The PFRA currently recommends up to five rows per section (2.6 km^2) on highly erodible soils (Figure 4.2.1). On the Canadian Prairies, shelterbelts that lower wind speeds by 30-40% are considered adequate (Ferguson *et al.*, 1977).

Shelterbelt density is an important factor in reducing wind speed. Caborn (1965) refers to the density of a shelterbelt as its structural "permeability". This concept

Figure 4.2.1: Closely spaced multiple-belt shelter project near Hodgeville, July, 1998.

differs from 'planting density' (the individual tree-spacing), but obviously the latter does influence the former. The density of a shelterbelt is chiefly determined by the species selected, the time of year, the design of the windbreak, as well as the planting method. Density varies widely in application. Most published guidelines suggest, rather cryptically, that a "moderately dense" windbreak is ideal. Some depictions of 'ideal' shelters show multiple rows of trees of various height and permeability that would effectively seal out any wind. However, a windbreak that is dense enough to act like a wall can also cause significant windward-side soil scouring, turbulent flow over the top, and, severe belt-end wind speed acceleration. This can result in greatly increased field wind velocities at field margins (Figure 4.2.2). Dense shelterbelts also tend to have an overall diminished effectiveness in reducing down-field wind speed (Figure 4.2.3). Additionally, overly dense plantings promote competition between trees for moisture, light and soil nutrients, ultimately resulting in poor tree health (Caborn, 1965; Logginov, 1964).

Shelterbelts that are too open also can have a net detrimental effect. It has been determined that tall shelters that are open at ground level can increase surface

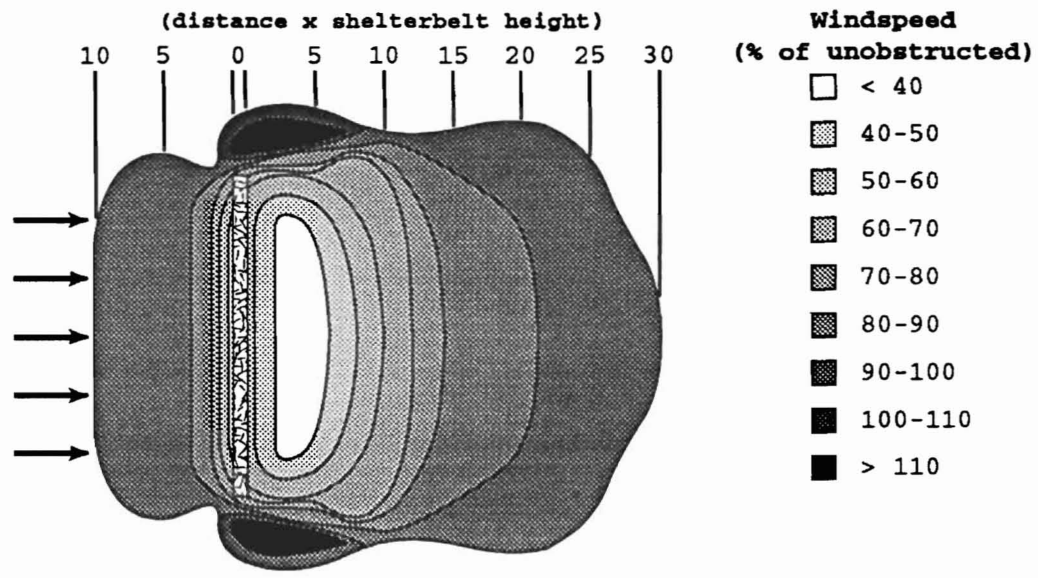


Figure 4.2.2: Flow around a moderately dense shelterbelt. Note the wind speed increase around the ends. The effect is similar for gaps in shelterbelts.
(after Caborn, 1965)

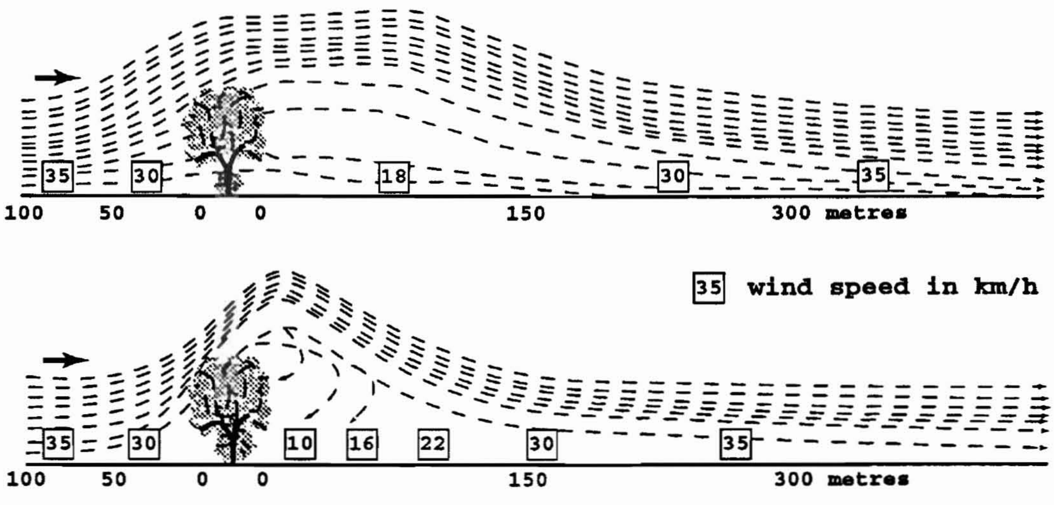


Figure 4.2.3: Effect of shelterbelt density on wind flow. Example is of a 10 metre moderately permeable shelter (upper), and a 10 m dense one (lower).
(after Caborn, 1965)

wind speeds though a venturi (funneling) action. This condition is commonly observed on the prairies and is induced by livestock damage (a particularly pervasive cause of ground-level porosity), species propensity (willow, for example), disease, age, or poor maintenance (Figure 4.2.4).

Figure 4.2.4: Result of neglect and probable herbicide overspray on shelterbelts near Eston, August, 1998.

The ideal density for most applications is difficult to quantify. Caborn (1965) has described an optimum density of 50-60%, equivalent to a permeability of 40-50%. This means the frontal coverage of the belt (the mass of leaves, stems and trunks when observed from the front) should appear to be approximately 60% of the total frontal area. However, this rule of thumb may be difficult to achieve in practice due to differing characteristics between species and unforeseen future growth deviations.

Shape is the third component of a shelterbelt's structure and refers to the arrangement of trees within shelterbelt rows. Multiple-row windbreaks commonly feature a row of dense shorter shrubs placed alongside a row of taller, more open trees, giving the shelterbelt a profile that can affect its wind modification character. Shape is usually more important in farm applications.

The orientation and location of field shelterbelts also play a role in wind reduction. Orientation is the cardinal direction along which shelterbelts are aligned. Ideally, windbreaks should be arranged so as to be perpendicular to the prevailing winds. In practice, orientation is strictly confined in Canadian Prairie applications. The land survey system imposed on Saskatchewan has determined that, for practical field management and land use efficiency, shelterbelts are always aligned on an east-west or north-south basis.

4.3 Control of Snow Deposition

Shelterbelt control of snow deposition entails much of the same theory that applies to the control of eolian erosion. Both processes are determined by the wind's velocity and its flow characteristics. Granular snow behaves in the same manner as soil particles when subjected to wind, whereby entrainment and deposition speeds similarly depend on the physical characteristics of the grains. Whereas moisture affects the erodibility of soil, temperature affects the transportability of snow, principally by causing changes in the physical characteristics of the grains. Erosivity remains the same for both materials, and is, therefore, equally modified by shelterbelts.

In practice, there are two primary objectives of shelterbelt snow management. In areas of low moisture, it may be desirable to have snow accumulate in large drifts. Fields that do not experience moisture shortages may be served best by having snow distributed more evenly across greater distances. Field studies have found that as much as 30% more water in the form of snow can be found in sheltered fields as opposed to unsheltered ones (Kort and Cherneski, 1989).

Snow deposition control is achieved by varying shelterbelt density. A more porous windbreak tends to distribute snow farther and more evenly. With any shelterbelt, density depends on many factors, but species selection is the main determinant for snow management purposes. Obviously, coniferous types maintain high density year round, while the permeability of deciduous belts depends upon the branch density characteristics of the trees. Bushy shrubs such as caragana remain more dense in winter than do more open species (Figures 4.3.1 and 4.3.2). The overall snow-trapping effect of shelterbelts is limited by the row spacing. With the wide spacing common to many applications, the effect over the entire field will not be as appreciable as with more closely spaced arrangements. However, a wide open neighbouring field will contribute more snow to the sheltered field than one which is also sheltered. This, and the other factors of shelterbelt snow management, require that caution be exercised in the planning of such windbreaks; especially where the shelter is to serve a dual purpose. That is, a thinned shelterbelt tends to distribute snow more evenly over a greater distance than a less porous one. However, in summer, it will offer very little soil loss mitigation and plant protection.

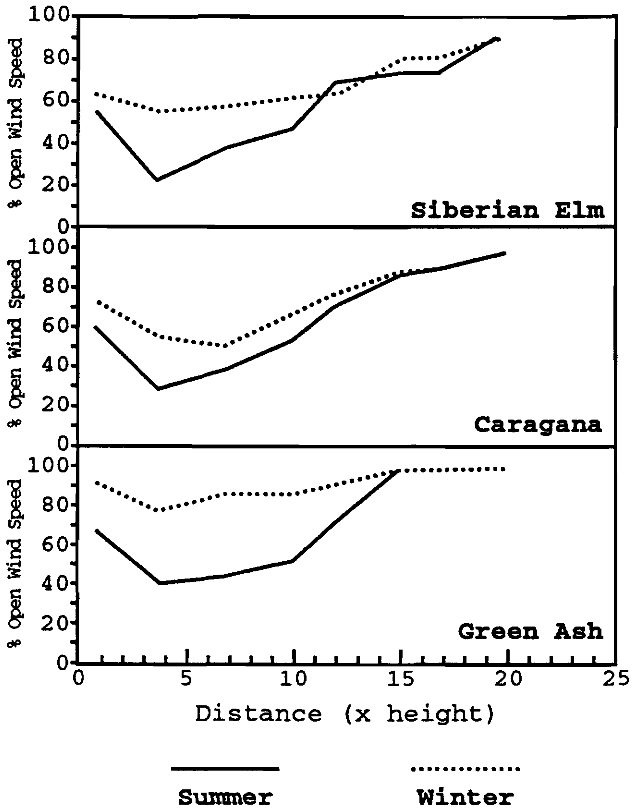


Figure 4.3.1: Difference in the summer and winter wind speed reduction capabilities of three common shelterbelt species.
(after PFRA, 1986)

4.4 Modification of Field Microclimate

Limited field microclimate modification may be achieved through the use of field shelterbelts. The reduction in wind velocity tends to raise field temperatures slightly near the windbreak. Additionally, the snow entrapment discussed previously can provide more moisture to the soil independent of growing season

Figure 4.3.2: Effect of caragana maintaining year-round density. In this case, snow and soil have been deposited in a large drift next to the prevailing windward side (observed near Outlook in March, 1999).

precipitation. Shelterbelts also increase the amount of moisture available to plants by reducing plant transpiration and soil evaporation. This, too, is accomplished through diminished wind speeds. A fairly dense line of trees 7.5 metres high will reduce evaporation up to 125 metres leeward (Soil Research Laboratory, 1949).

One shelterbelt effect detrimental to crop production is the relatively high amount of moisture required by the trees. However, it has been demonstrated that shelterbelts can ideally provide a net improvement in crop yields at a distance of 1.5 to 10 times the height of the shelterbelt (Kort and Holzapfel, 1991). According to PFRA research, sheltered fields typically show at least a 5% yield increase. American and Russian studies have claimed even greater productivity increases (Frank *et al.*, 1976; Logginov, 1964). Generally, the yield increases seen in sheltered fields is considered a positive net gain when production losses owed to shelterbelt moisture consumption and space requirements are accounted for. However, the productivity tradeoff will vary locally, and must be calculated by the landowner.

PFRA studies have concluded that the microclimatic enhancements achieved through the use of shelterbelts allow for significant crop diversification in many prairie locations. Certain vegetable crops including potatoes, cucumbers, cabbage, and peas have been found in trials to produce higher yields when sheltered (PFRA, 1987). This increase is attributed to a mean increase of 1-2°C for afternoon and evening temperatures, greater soil moisture and reduced wind velocities. Not mentioned in the studies is the effect of diminished winds on frost risk for long-season specialty crops.

4.5 Other Shelterbelt Benefits

Numerous other agricultural benefits may be achieved through the planting of field shelterbelts. For example, there are certain soil enhancements including increased organic matter and nitrogen fixation to be gained. Another example is farm product diversification fulfilled by the shelterbelt trees themselves. This is achieved with the cultivation of fruit-bearing species such as seabuckthorn and chokecherry.

Wildlife shelter, in particular, is of increasing importance. There may be tangible agricultural benefits of such shelter. Limited research conducted on the northern United States Plains has found that shelterbelts of several types encourage certain predatory bird species to populate lands they have never before occupied (Gilmer, 1986). This obviously has important ecological ramifications for field rodent populations and other agricultural-land communities. Ultimately, the effects on agricultural ecology should gain importance relative to the largely aesthetic or conservation-based reasoning that lies behind the promotion of wildlife shelters to date.

4.6 Shelterbelts as a Hazard Mitigation Strategy

Natural hazards may be viewed as systematic human-environmental interactions (Kates, 1971). These systems can be broken into three primary components: 'determinants', or causes, which lead to the manifestation of the hazard as an 'event', (referred to as a disaster in extreme cases), necessitating human adjustments or 'responses'. Field shelterbelts are, in effect, a mitigation strategy for two common natural hazards: meteorological drought and damaging winds. An example agricultural hazard system model (Figure 4.6.1) has been formulated for this study for which the determinants, hazards, effects, and adjustments are illustrated.

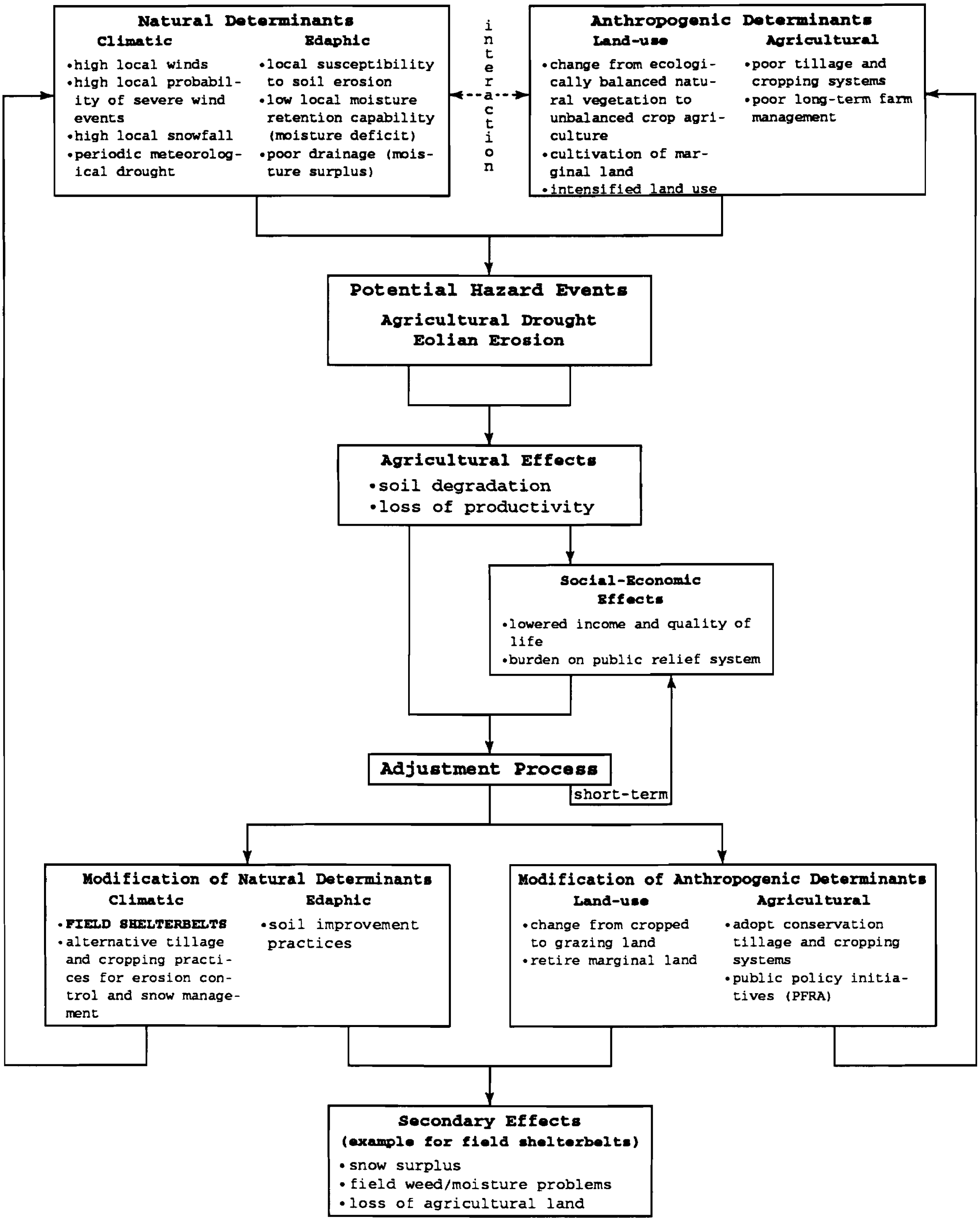


Figure 4.6.1: System model for agricultural hazards mitigated by field shelterbelts.

Chapter 5
Shelterbelt Distribution Characteristics

5.1 Spatial and Historical Variation in Distribution

5.1.1 Fifty-year distribution patterns

A primary objective of this research is to illustrate spatial variation in Saskatchewan's field shelterbelts. This is accomplished by totaling all trees distributed to every location in the study area and mapping the results. Here, the minimum mapping unit is the township. Uniformity of area is the reason this unit was chosen in preference to other defined polygons such as RMs or agricultural census sub-divisions. Except for townships lying along the last ranges (for example, Twps.3-18, Rge.30, W.2), each township measures six miles by six miles. Additionally, the township to which trees were shipped is listed on almost every PFRA record. Usually, the shipping destination is the 'home quarter', and it is for this location that shelterbelt mileage is calculated. Unfortunately, there is often no way of knowing if the trees were actually planted in the 'home' township or on alternative sites in other townships. Some spatial error undoubtedly exists, but the majority of orders are believed to be planted in the township for which they are mapped. Any erroneously mapped values should usually be misplaced by only one township. This mapping error is discussed further in Chapter 6.

Based on distance calculations described in Section 2.2, five shelterbelt 'density rating classes' have been assigned and are defined in Table 5.1.1.

Table 5.1.1: Shelterbelt density ratings used in the distribution mapping.

Shelterbelt Density Rating	**Linear Distance: 50-year map (miles per Twp.)**	**Linear Distance: 5-year maps (miles per Twp.)**
Very High	>40	>16
High	20-40	8-16
Moderate	10-20	4-8
Low	5-10	1-4
Negligible	0-5	0-1

When all trees shipped between 1949 and 1998 are mapped for each township, particular shelterbelt concentrations become apparent (Figure 5.1.1). The main clusters are located south of Swift Current, in a band stretching along the South Saskatchewan River from Lake Diefenbaker to Saskatoon, and between Tramping Lake and Cut Knife. Several

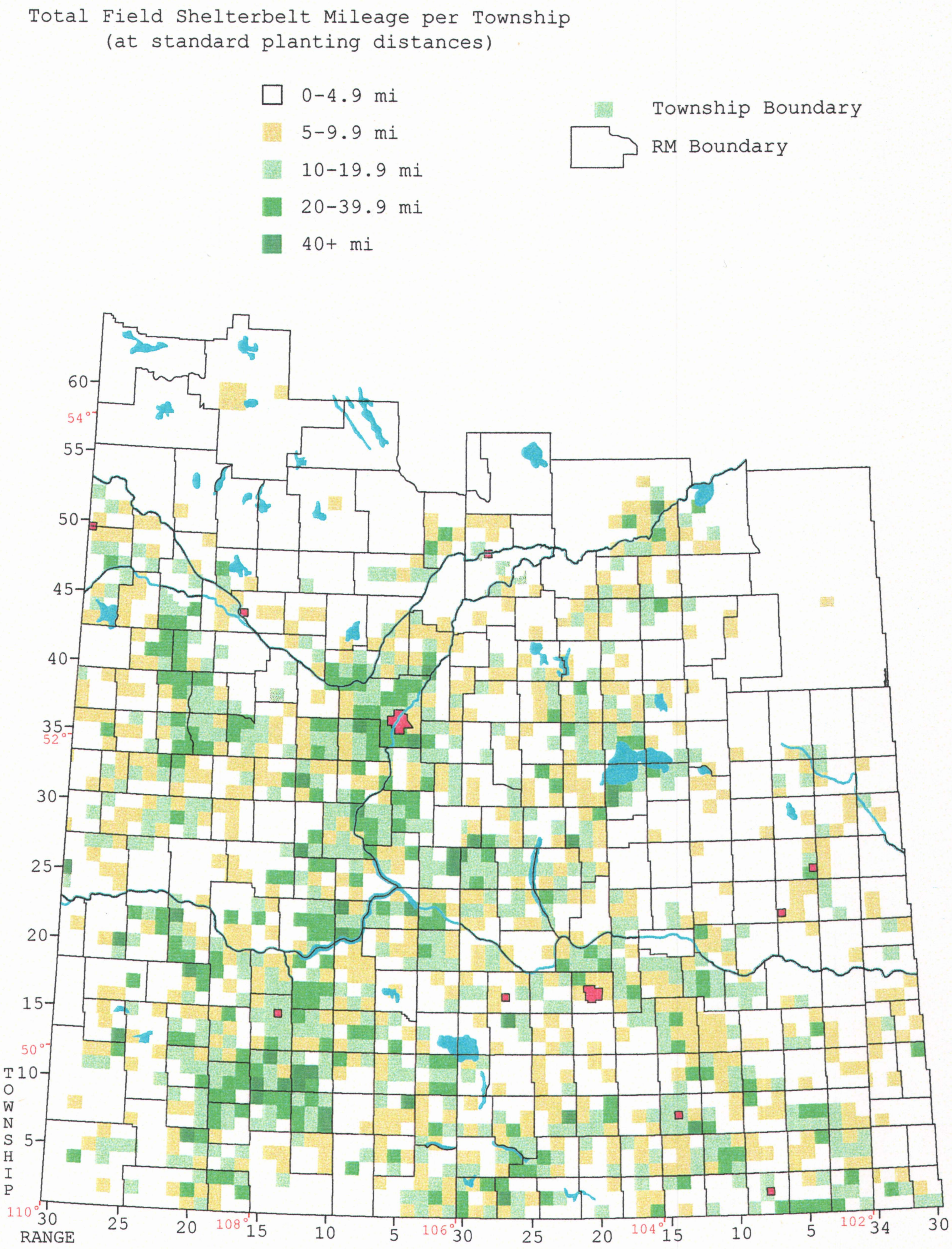


Figure 5.1.1: Saskatchewan field shelterbelt distribution, 1949-98.

lesser concentrations are also evident. Notable among these are the Willow Bunch, Weyburn-Estevan, Davidson, Quill Lakes, and Nipawin districts. Areas conspicuous for their dearth of field shelterbelts include the eastern parkland, the Cypress Hills, much of the Great Sand Hills, and most of the northern parkland—boreal transition farmland (consult Figure 3.1.2 for place locations).

5.1.2 Five-year distribution patterns

Ten temporal map intervals, each spanning five years, have been defined in order to chart historical shelter planting trends. The resulting five-year maps (Figures 5.1.2a through 5.1.2j) show a number of notable patterns. The 1950s maps show only scattered shelterbelt distribution with few discernable 'projects'. Exceptions are the more consolidated efforts near Outlook-Macrorie, Eyebrow, and Wilkie-Scott. Into the early 1960s, plantings were more concentrated, but only in select areas of the province. This time, land situated between Outlook and Kenaston, as well as the Lucky Lake-Beechy and Swift Current districts were the places of greatest activity.

It is not until the mid-1960s that specific shelterbelt foci become apparent. More province-wide planting was occurring. The Wilkie-Scott-Cut Knife,

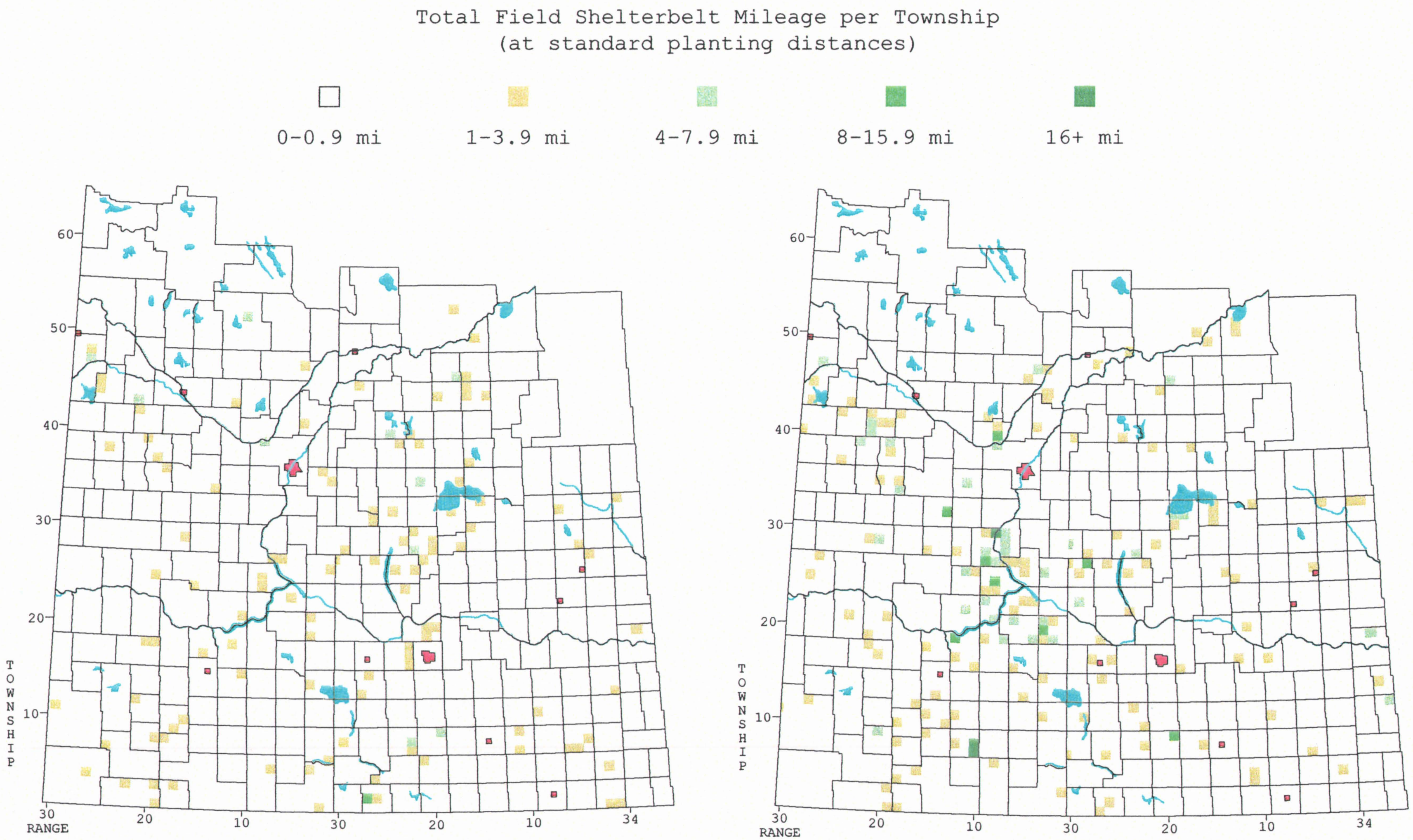


Figure 5.1.2 a-j: Saskatchewan field shelterbelt distribution, 1949-53 **(a)** **(left)**, 1954-58 **(b)** **(right)**, **(c-j: following pages)**.

Total Field Shelterbelt Mileage per Township
(at standard planting distances)

0-0.9 mi	1-3.9 mi	4-7.9 mi	8-15.9 mi	16+ mi

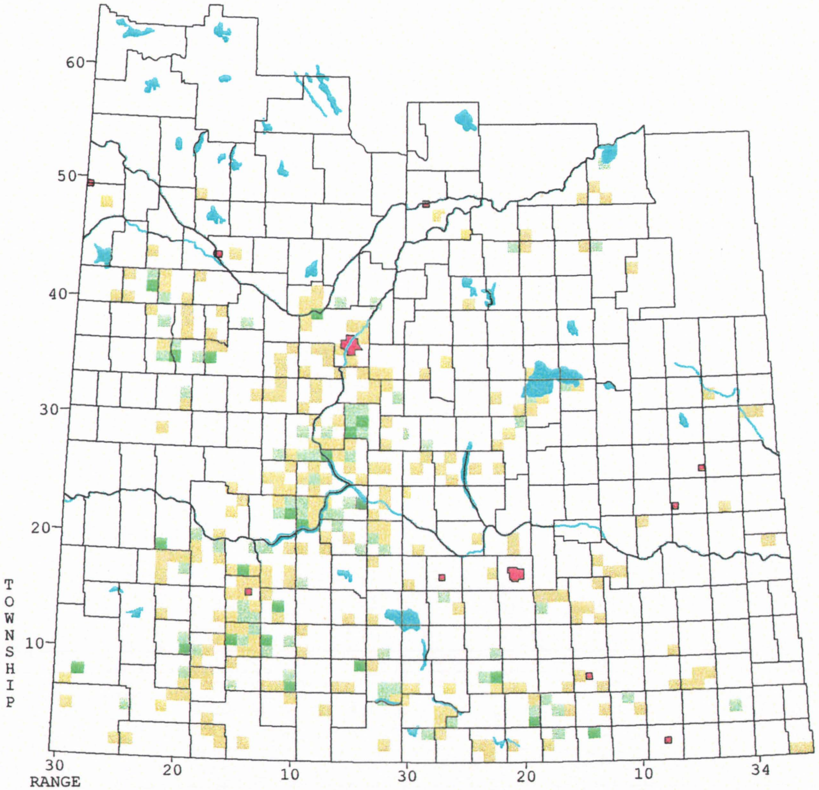


Figure 5.1.2c: 1959-63

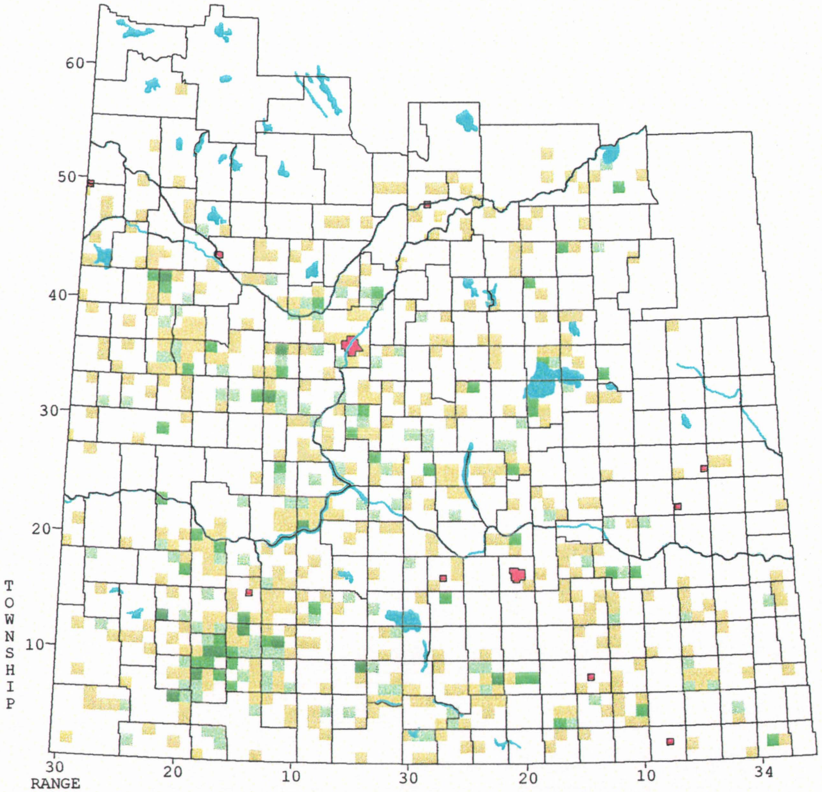


Figure 5.1.2d: 1964-68

Total Field Shelterbelt Mileage per Township
(at standard planting distances)

0-0.9 mi	1-3.9 mi	4-7.9 mi	8-15.9 mi	16+ mi

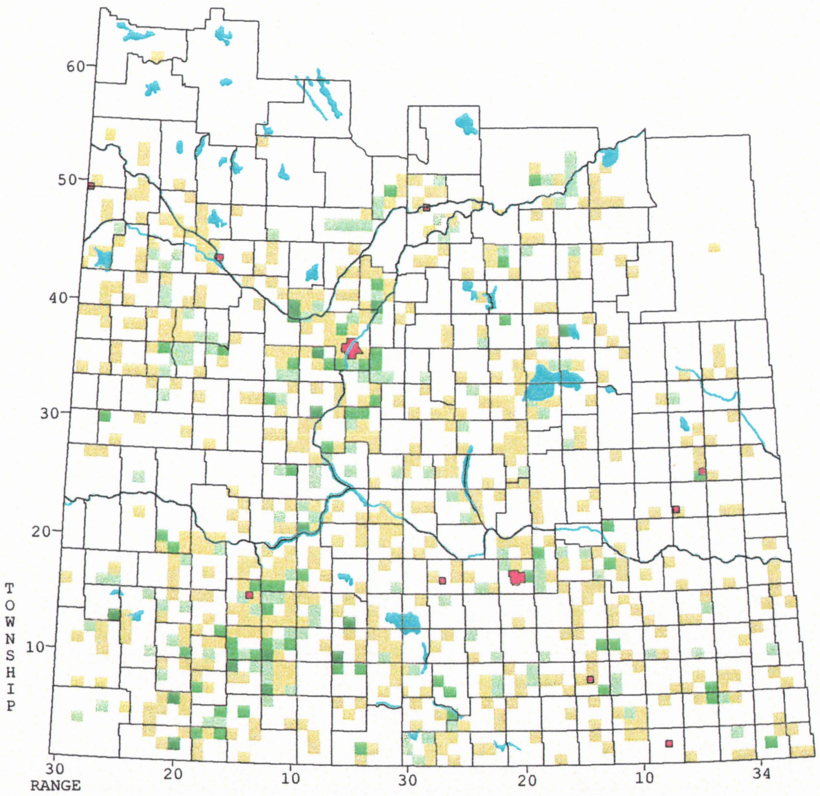


Figure 5.1.2e: 1969-73

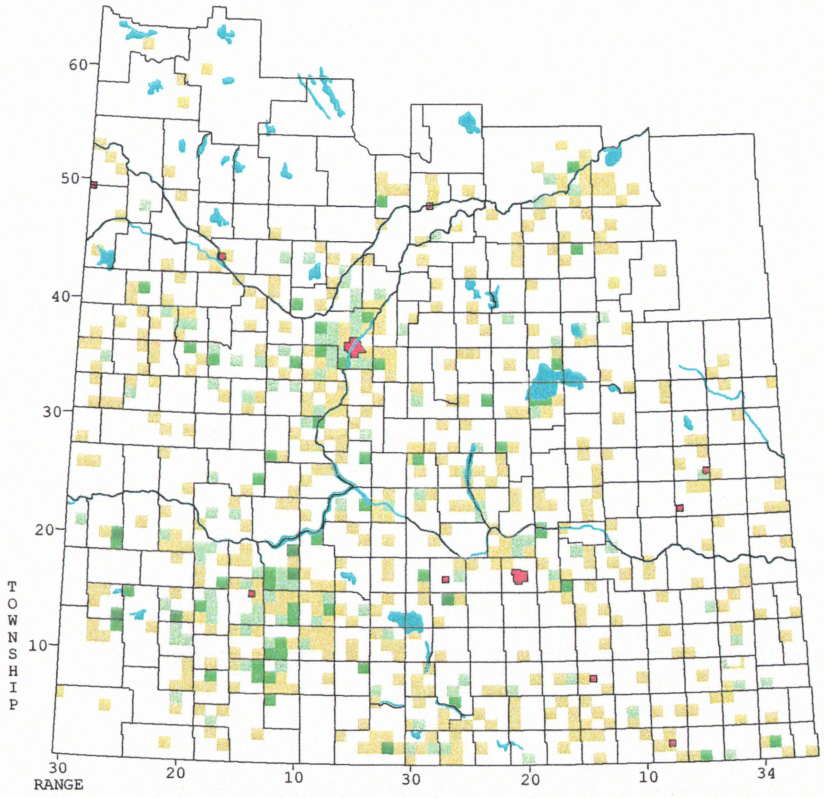


Figure 5.1.2f: 1974-78

Total Field Shelterbelt Mileage per Township
(at standard planting distances)

0-0.9 mi | 1-3.9 mi | 4-7.9 mi | 8-15.9 mi | 16+ mi

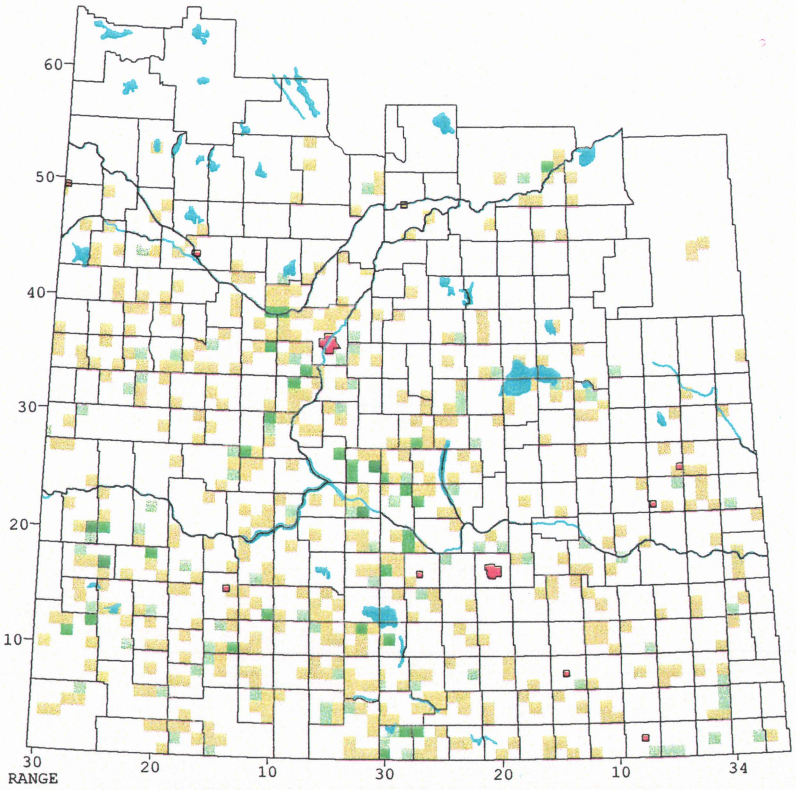


Figure 5.1.2g: 1979-83

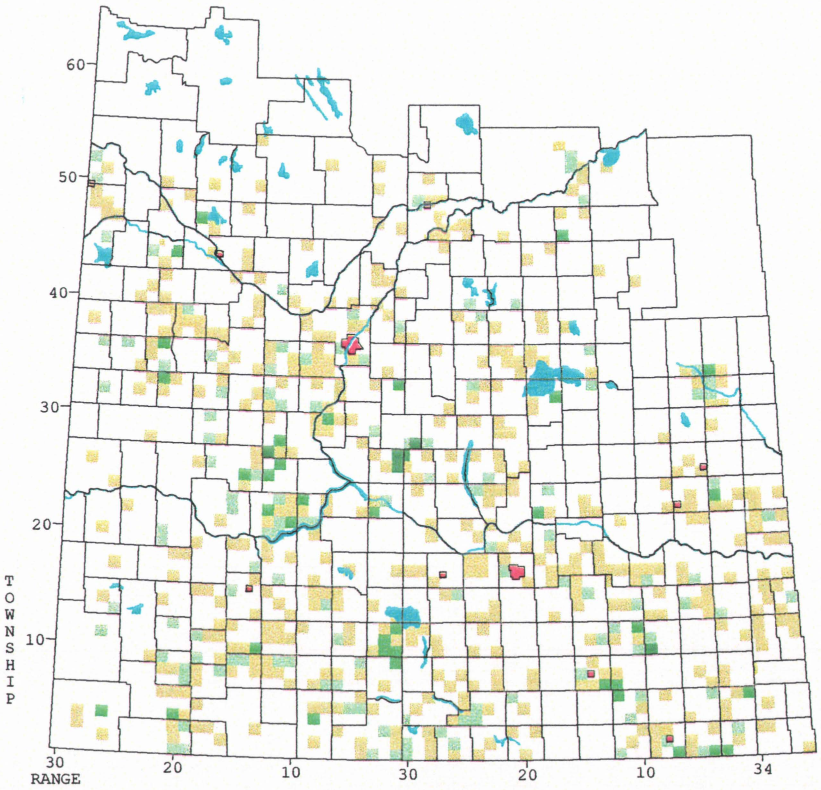


Figure 5.1.2h: 1984-88

Total Field Shelterbelt Mileage per Township
(at standard planting distances)

0-0.9 mi   1-3.9 mi   4-7.9 mi   8-15.9 mi   16+ mi

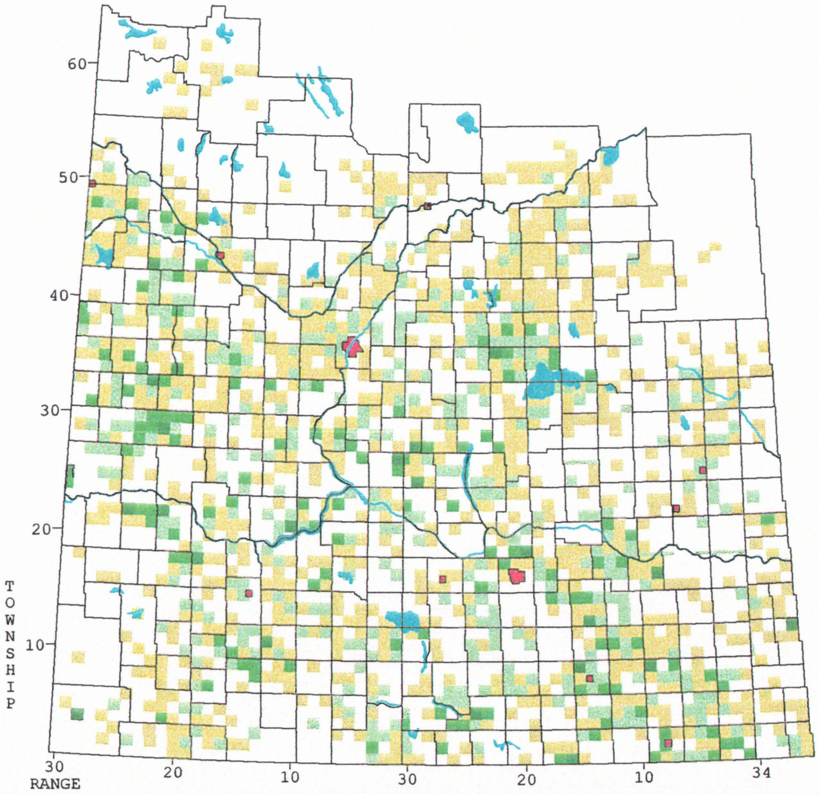


Figure 5.1.2i: 1989-93

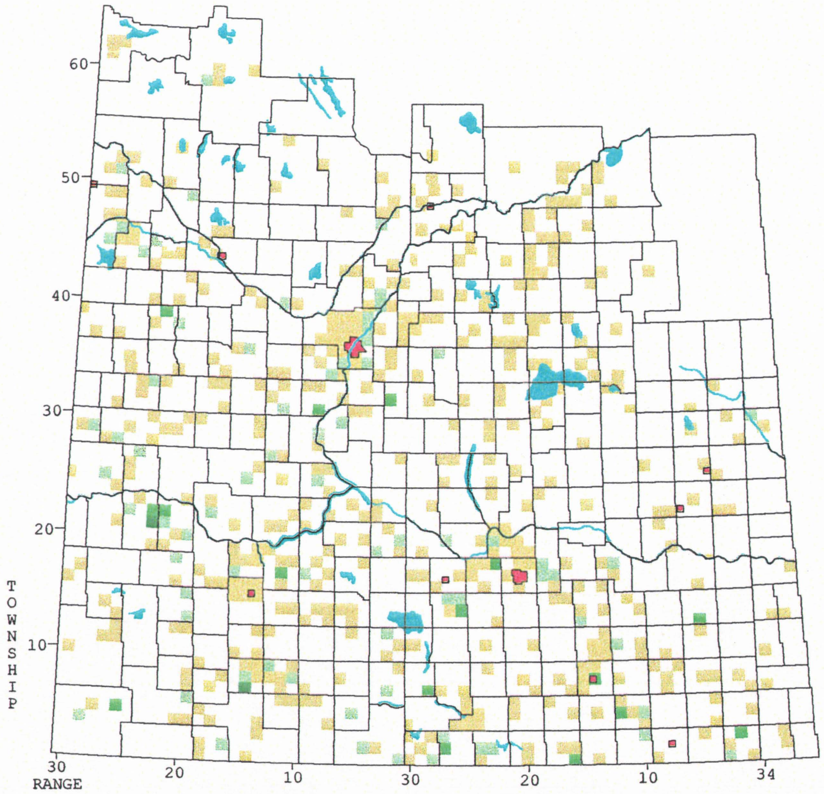


Figure 5.1.2j: 1994-98

Outlook-Kenaston, and Beechy developments continued, while the Perdue and Ogema areas initiated projects. By far, the most active area was a large portion of south-west Saskatchewan, south of Swift Current, extending south-west to Eastend. This latter region has come to represent the most concentrated zone of shelterbelt planting over the 50-year record.

During the 1970s, distribution became more spatially uniform. The Wilkie-Scott, Outlook-Kenaston and Swift Current areas showed continued planting in the early 1970s, but this was reduced by the latter part of the decade. New planting foci were the Saskatoon and Nipawin-White Fox districts as well as a large tract east of Swift Current. By the 1980s, placement of new shelterbelts became more spatially localized and generally less concentrated throughout the province. Notable exceptions were the Davidson, Old Wives Lake, Beechy, and Sturgis-Canora areas.

Following a trailing off in shelterbelt tree distribution through the 1980s, the early 1990s showed a substantial increase in activity. Nearly all cultivated portions of Saskatchewan received trees for field shelterbelts. Much of south-east Saskatchewan, as well as the Kindersley, Muenster, and Davidson districts were places of substantial planting activity. However, at the time of writing, the number of new field shelterbelts being placed across Saskatchewan has dwindled. Only landowners in the environs of Saskatoon and Regina are demonstrating a maintained interest in field shelter.

5.2 Species Distribution

5.2.1 Predominant species

Several species and varieties of trees have been recommended for field shelterbelt use over the past fifty years. Some have been found to be highly adaptable and fully serviceable over the long-term while others have proven otherwise. The long list of species distributed by the PFRA to Saskatchewan producers since 1949 is available for consultation in Appendix B. This section outlines only the most important ones.

In terms of shelterbelt miles, and especially, total number of trees planted, one species stands out. Since 1949, caragana has accounted for nearly four-fifths of all trees distributed and 42% of the total miles planted in Saskatchewan for field-type shelterbelts (see Table 5.2.1). *Caragana arborescens* (the most common variant) is a densely growing leguminous shrub. It provides good protection, has excellent cold and drought tolerance, grows moderately quickly with relatively low maintenance, and has adapted to all but the more poorly drained portions of Saskatchewan. Although its importance has waned in the past decade, it is still delivered to land owners in large numbers.

Table 5.2.1: Predominant field shelterbelt species, 1949-98.

Species	Number	Calc. Dist.(mi)	Total % Dist.	Dist. Rank
Caragana	46,284,215	8,766	41.9	1
Ash	4,583,015	5,208	24.9	2
Siberian Elm	2,991,441	2,359	11.3	3
Willow	845,915	1,021	4.9	4
Man. Maple	706,150	802	3.8	5
Conifer	420,740	651	3.1	6
American Elm	481,840	547	2.6	8
Chokecherry	937,165	532	2.5	9
Poplar	465,060	528	2.5	10
Lilac	875,550	497	2.4	11
Other	774,310	605	2.9	7
Totals	**59,365,401**	**20,913**		

Recently, green ash (*Fraxinus pennsylvanica*) has become the species of choice for Saskatchewan shelterbelts. One quarter of all field shelterbelt mileage established since 1949 has been planted with green ash. Its proportionate use has steadily increased since the early 1980s, peaking at over 1,000 calculated miles planted in 1991. Green ash is native to the Canadian prairies and is drought and winter tolerant. Mature ash shelters are moderately open at their base, but this is considered to provide more uniform snow distribution (PFRA, 1992). They are commonly inter-planted with more dense, shrub species such as caragana or lilac. Other stated benefits of green ash are an upright form minimizing field encroachment and a deep vascular tap root minimizing competition with adjacent crops (PFRA, 1992). The main disadvantage of this tree is its relatively slow maturation rate.

Calculated from the distribution records, one out of ten field shelterbelt miles since 1949 was planted with Siberian elm (*Ulmus pumila*). It was the favoured species of the late-1960s and 1970s. It has a very fast growth rate, dense crown, and is drought tolerant. It was planted in large numbers in the past, but after long-term service was found to exhibit several undesirable traits. Chief among these are its short 30-year life-span, and its tendency toward structural weakness. Its roots also spread laterally, interfering with crops. Its substantial seed production can induce a weed nuisance in fields.

Various willow varieties (*Salix* spp.) have been used for Saskatchewan field shelters to varying degree since 1949. These trees are natural to moist areas throughout the prairies and will, therefore, grow in most places within the study area. They can withstand moderate spring flooding but do rather poorly in dry locations. They provide good protection, but with maturity, tend to develop open bases (PFRA, 1992).

A variety of coniferous species have been planted in limited numbers as field shelter for much of this century. They are principally recommended for farm-yard shelter where they provide year-round protection and pleasing aesthetic value. In field use, white spruce (*Picea glauca*), Colorado spruce (*P. pungens*), and Scots pine (*Pinus sylvestris*) are the principal types. Larch varieties such as *Larix sibirica*, have also been distributed to several sites since 1949. White spruce is the only native conifer shipped, but its use is restricted by its comparatively greater moisture requirements. The more drought-tolerant Colorado spruce has outnumbered it in application by three to one. Scots pine is ideally suited to sandy sites. Larch has been limited in its field shelter service (fifty calculated miles since 1949). None of the conifers thrive when planted in exposed locations.

Several other tree and shrub species have been used for field shelter. Many of these have more restrictive environmental requirements, or have more specialized uses. Manitoba maple (*Acer negundo*), American elm (*Ulmus* *americana*), and poplar (*Populus* spp.), as well as chokecherry (*Prunus virginiana*) and lilac (*Syringa* spp.) are the main alternatives.

5.2.2 Spatial variation in species

The major field shelterbelt species such as caragana and green ash are distributed equally across the study area. These are 'universal' species that have been found to do well throughout the province, except where localized adverse habitat conditions exist. Other species, such as willow and conifers are more spatially restricted (Figure 5.2.1).

All types of willow planted between 1949 and 1998 were combined and mapped. The largest consolidation of willow shelterbelts is located in the Nipawin—Carrot River district. Lesser concentrations may be found north-east of the Quill Lakes, in the Shellbrook area, and near Saskatoon. Most willow field shelterbelts are planted in locally favourable environments, especially in the relatively moist north-east. Additionally, as mature willow shelterbelts tend to be rather open at ground level, it also may be assumed that in areas of lower wind erosion risk, this growth characteristic is not considered as detrimental as it might be in other locations.

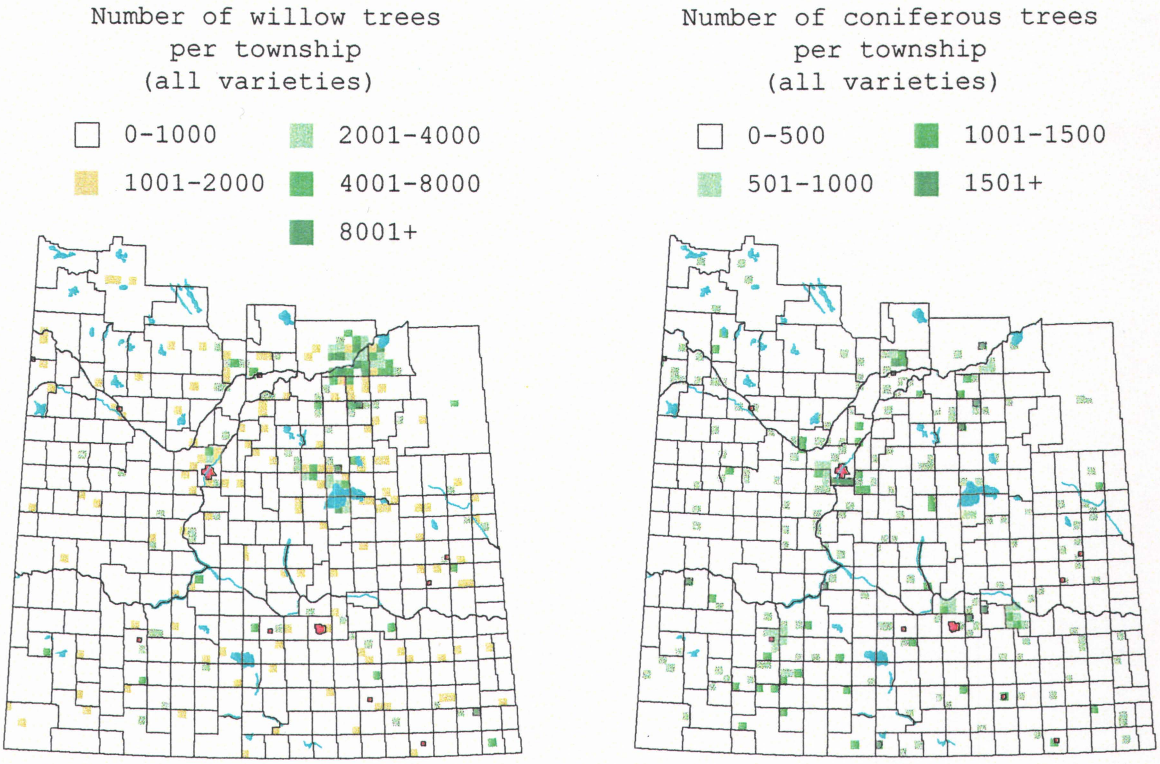


Figure 5.2.1: Willow and conifer distribution, 1949-98 (expressed as number of trees per township).

All coniferous species (larch varieties excepted) were similarly combined and mapped. These tend to be concentrated in the environs of urban centers, namely Swift Current, Regina (Lumsden), Saskatoon, and Prince Albert. The other significant conifer concentration surrounds the PFRA Shelterbelt Centre at Indian Head. Obviously, non-environmental considerations are involved in these placements. It could be suggested that the urban-area concentrations reflect the greater number of smaller 'acreage' farms in these locations. It is possible that, for these, aesthetic qualities are of a higher priority when selecting shelterbelt species (Figure 5.2.2). The concentrated plantings near Prince Albert and Indian Head would seem to be associated with the distribution centers situated at these locations.

Figure 5.2.2: Double-row mature spruce field shelterbelt near Muenster. Plantings such as this are relatively rare in Saskatchewan. This one has been planted and maintained by an institution. (observed July, 1998)

5.2.3 Historical variation in species

Some species have been favoured for only a certain historical period whilst others remain popular. Figure 5.2.3 shows specific trends over the fifty-year study period. Caragana has always been a main choice, although green ash has become the dominant species lately. Certain species, such as American elm and Siberian elm have largely disappeared from the record in recent years; the former due to concerns over Dutch elm disease, and the latter because of suitability problems described previously. Poplar is another example of a species used more widely for only a certain period; in this case, the 1960s-1970s (Figure 5.2.4). Species such as willow, Manitoba maple, chokecherry and lilac have been used in limited numbers for much of the study period, commonly for purposes for which these types are individually well-suited.

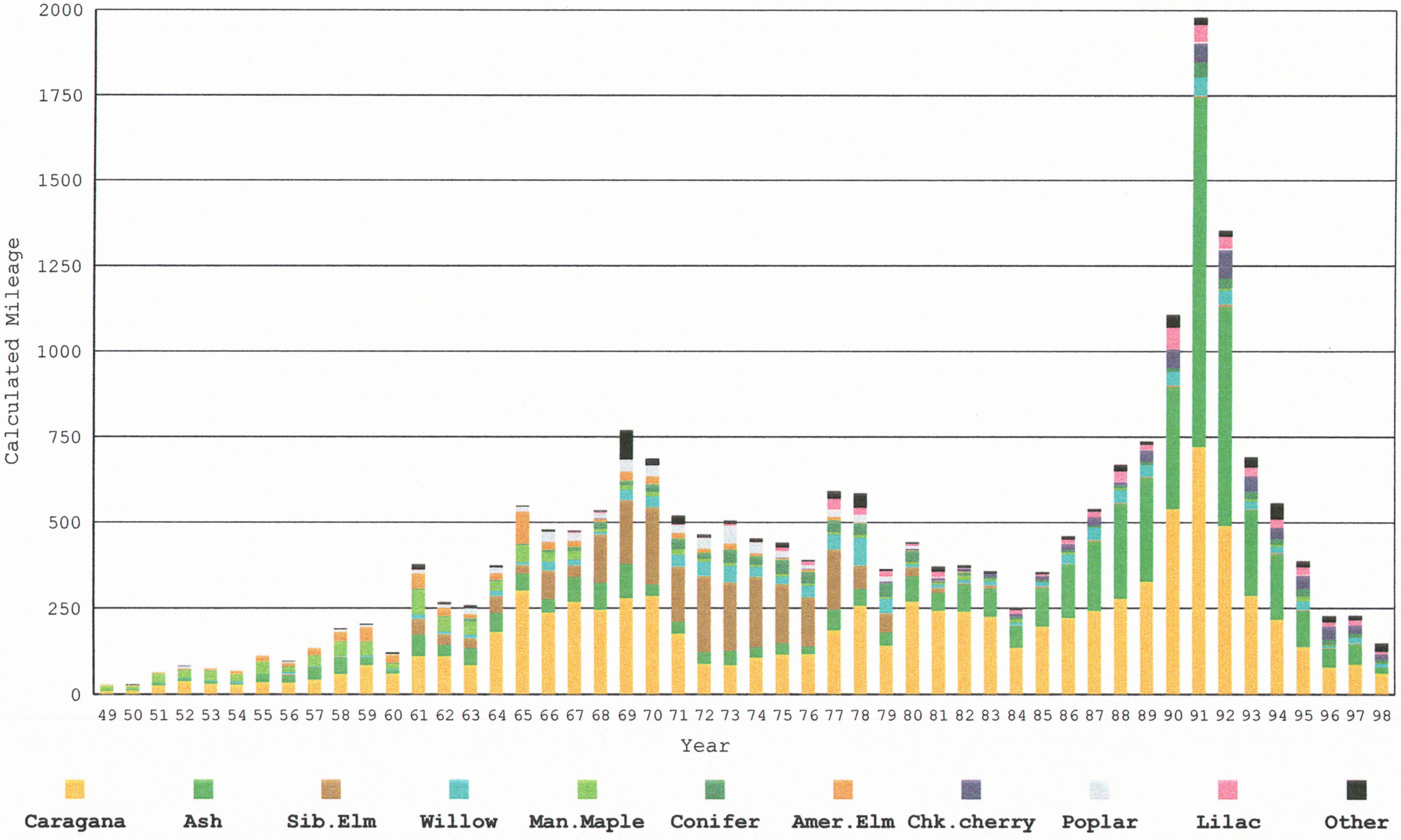


Figure 5.2.3: PFRA tree distribution by species, 1949-98.

Figure 5.2.4: Mature poplar field shelterbelt near Kelvington, July, 1998. *Populus* spp. have never been used in large numbers due to moisture constraints in many places. In locations where they do grow well, they provide substantial shelter.

Chapter 6
Location Case Studies
-Determinants and Shelterbelt Application-

6.1 Introduction

Distribution mapping has demonstrated that field shelterbelts are concentrated in particular areas within Saskatchewan. The patterns suggest that various location-specific factors have influenced landowner decision-making in the placement of field windbreaks. To assist in discerning the principal determinants of shelterbelt spatial patterns, five areas are examined in greater detail using methodology described in Chapter 2.

Several of the shelterbelt determining factors, both physiographic and human, change spatially across Saskatchewan. The case locations have been selected so as to represent this variation and are discussed in this chapter, in order, from south to north. The warm, mixed grassland areas of southern Saskatchewan, represented by the Midale and Cadillac cases, are outlined in the first two studies. These are followed with discussions of the dry central grasslands of Davidson-Bladworth, the more temperate parkland of Wilkie-Unity, and finally, the climatically-moderate forest transition zone surrounding Nipawin. Wind velocities also vary across the province, highest in the south-west/central regions, calmer in the parkland north. Soils grade from south to north reflecting the transition between ecological zones. Brown Chernozems are represented in the dryer portions of the mixed grassland, grading to dark brown to black Chernozems in the moist mixed grasslands and parkland. Due primarily to climate restrictions, crop production is lowest in the southern locations and highest in the northern-most cases. Because of this, grazing and pastureland is more prevalent in the Midale and Cadillac regions. However, it is in the lower wind erosion risk, higher productivity, Wilkie-Unity and Nipawin cases that some of the highest concentrations of field shelterbelts are found.

6.2 The Midale Focus Area

6.2.1 Area description

The Midale study location is designated as a rectangular portion of south-east Saskatchewan, situated between 103° and 105° West longitude and 49° and 50° North latitude (refer to Figure 6.2.1). Climate data recorded at the Weyburn meteorological station (Environment Canada ID 4018760) from 1953 to 1992 reveals that the Midale January daily mean was -15.2°, and that for July, 19.4°. Normal annual rain and snowfall was 298 mm and 94 mm respectively. Based on 1963-92 normals, the average annual Weyburn wind

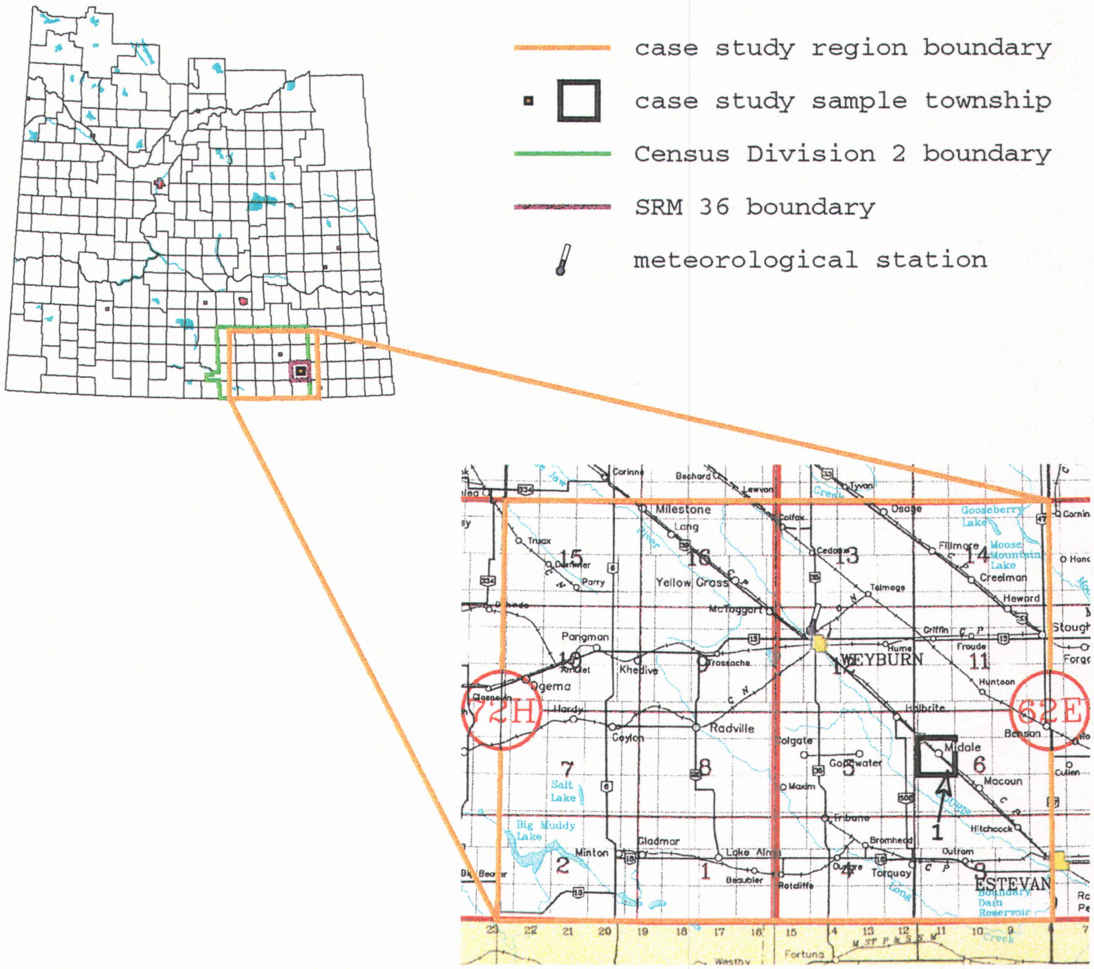


Figure 6.2.1: The Midale case study location (using Sask. Property Management Corp. *NTS Index Map*, 1991). The numbered point (1) corresponds to figure 6.2.3.

speed is 15.8 km/h, with velocities highest in May and lowest in July and August. The prevailing wind direction is decidedly north-west/south-east, blowing from these directions on approximately six out of ten occasions.

Formed in a 'moist mixed grassland'/'mixed grassland' ecoregion (Acton *et al.*, 1998), Midale soils are typically brown to dark brown chernozems with brown to dark brown solonetzics in several places. Texturally, most soils are loamy, excluding a large area of glaciolacustrine origin clay soils north-west of Weyburn. Much of the region is at moderate risk of wind erosion.

6.2.2 Land-use and agriculture

The Midale region is entirely farmland. At the time of the CLI survey, nearly 99% of all land was either under cultivation, or was being used as grazing land (Table 6.2.1). Open water and wetland is minimal, and woodland is nearly non-existent.

A CLI-based land-use map has been graphically overlaid with the wind erosion risk and shelterbelt distribution maps (Figure 6.2.2). The accompanying Table 6.2.2 provides a description of the land-use type, wind erosion risk and shelterbelt density zones portrayed on the map. The shelterbelt density ratings correspond to those listed in Table 5.1.1.

Table 6.2.1: Midale region land-use (with area and proportion of total). Area values are approximations based on interpretation of a digitized mosaic of CLI maps.

Land-Use Type	**Area (km^2)**	**% of Total**
Cropland (incl. summerfallow)	9,491	58.8
Rough Grazing	6,230	38.6
Improved Pasture	196	1.2
Water	129	0.8
Built-up Areas	42	0.3
Woodland, Non-Productive	21	0.1
Barren	9	0.1
Quarries/Mines	3	0.0
Woodland, Productive	3	0.0
Recreation Areas	2	0.0
Wetland	1	0.0
Total	**16,126**	**100.0**

The map shows broad cultivated tracts with rangeland and pasture situated mostly in the drier south-west portion of the region, but also along a bisecting north-west/south-east diagonal band corresponding to the sandy-stony Souris River Plain. Although crop agriculture dominates the Midale region, production rates are comparatively low. 1961, 1985 and 1988 were particularly bad years for crop returns; a trend seen in many parts of Saskatchewan. Agriculture has become more diversified as more land is seeded with oilseeds and specialty crops. Midale area producers employ a balance of conservation and traditional tillage techniques. Summerfallowing has long been popular in the area, peaking at one third of all improved land in the early 1980s. However, its use has diminished somewhat over the past decade and 30% of seeded land is now left untilled. Average annual farm income is moderate ($27,000 in 1996). However, in SRM 36, (the RM containing the sample township), the 1996 per-person mean annual income was much

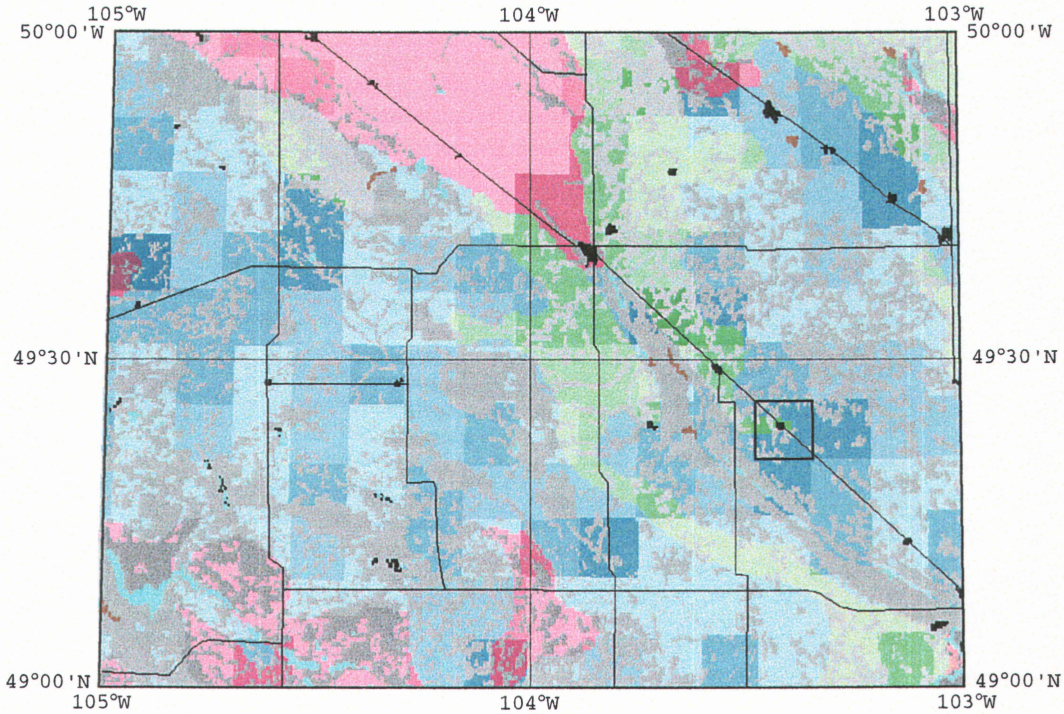


Figure 6.2.2: Midale land-use/wind erosion risk/shelterbelt density overlay. Refer to Table 6.2.2 (following page) for an explanation of the zones. The sample township is outlined.

Table 6.2.2: Midale land-use, wind erosion risk and shelterbelt distribution zones. (refer to Figure 6.2.2)

Map zone	**Area (km^2)**	**% total area**	**Zone description (Land-use, Wind Erosion Risk, Shelterbelt Density)***
	8	0.0	Cropland, Severe Risk, Negligible Density
	21	0.1	Cropland, High Risk, Very High Density
	69	0.4	Cropland, High Risk, High Density
	203	1.3	Cropland, High Risk, Moderate Density
	180	1.1	Cropland, High Risk, Low Density
	1269	7.9	Cropland, High Risk, Negligible Density
	60	0.4	Cropland, Moderate Risk, Very High Density
	580	3.6	Cropland, Moderate Risk, High Density
	1465	9.1	Cropland, Moderate Risk, Moderate Density
	1630	10.2	Cropland, Moderate Risk, Low Density
	2341	14.6	Cropland, Moderate Risk, Negligible Density
	30	0.2	Cropland, Low Risk, Very High Density
	72	0.4	Cropland, Low Risk, High Density
	483	3.0	Cropland, Low Risk, Moderate Density
	376	2.3	Cropland, Low Risk, Low Density
	658	4.1	Cropland, Low Risk, Negligible Density
	13	0.1	Rough Grazing/Impr.Pasture, Severe Risk
	771	4.8	Rough Grazing/Impr.Pasture, High Risk
	4447	27.7	Rough Grazing/Impr.Pasture, Moderate Risk
	1167	7.3	Rough Grazing/Impr.Pasture, Low Risk
	130	0.8	Water/Wetland
	24	0.1	Woodland
	56	0.3	Built-up/Recreation/Mines and other Non-ag. Areas
	256		Unclassified

***Notes:**

1) Colour indicates cropland.
2) Colour groups indicate wind erosion risk classification.
3) Shading corresponds to shelterbelt density. Density is mapped at a township-level resolution.
4) Unclassified land represents map edge area and is the result of map overlay inconsistencies. Area proportion calculations do not include 'unclassified' cells.
5) Area values are digitally interpreted from the three base maps which have each been converted to the 'Lambert Conformal Conical' projection used by Saskatchewan Property Management Corp. (1991) *Saskatchewan NTS Index Map*.

higher at $35,500. Undoubtedly, substantial petroleum extraction in that area plays a large economic role.

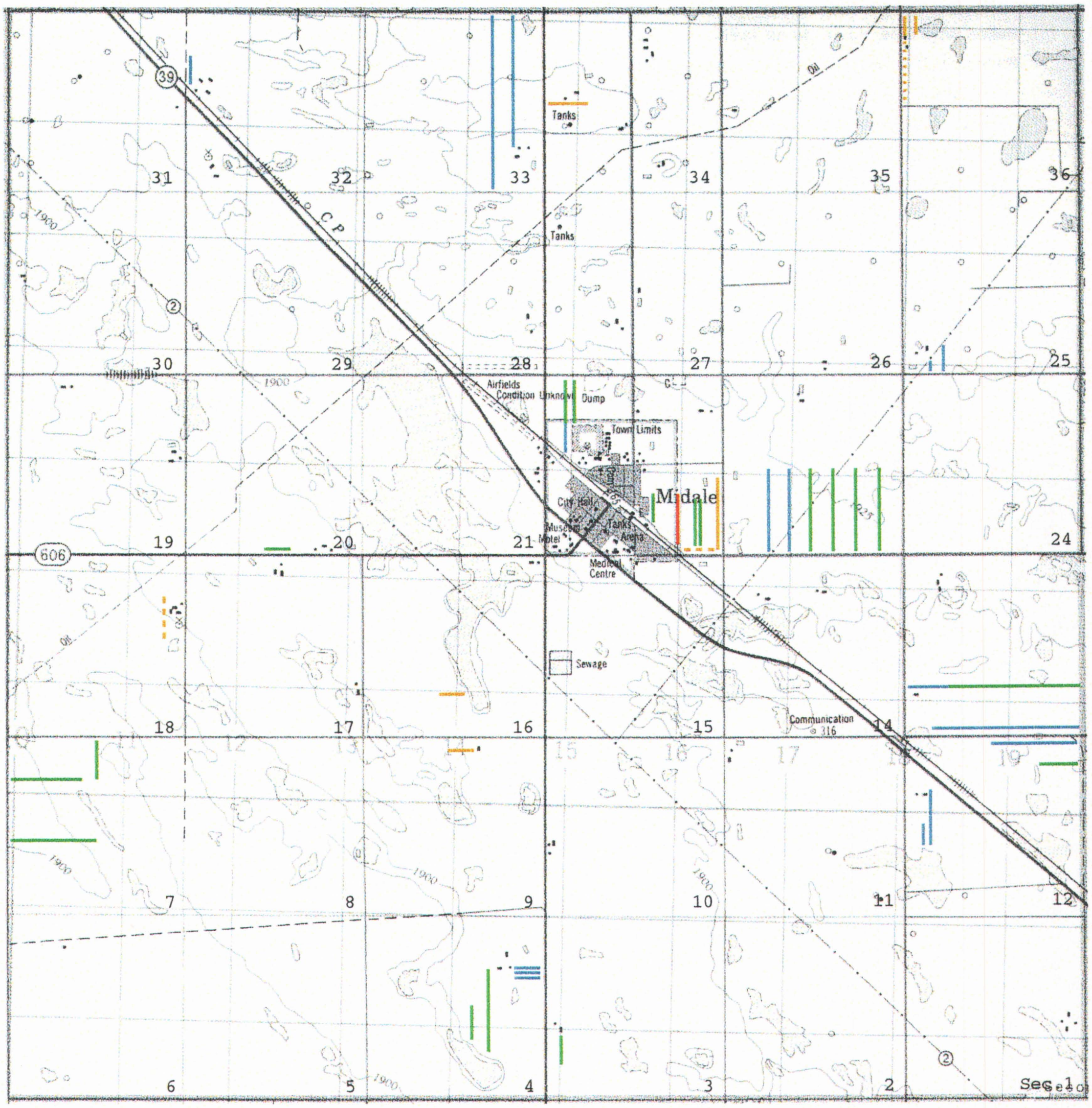
6.2.3 Historical shelterbelt change

The township selected for individual shelterbelt survey immediately surrounds the town of Midale, at the centre of SRM 36. It was chosen for its mid-point locality along a concentrated band of shelterbelt plantings, adjacent to Provincial Highway 19, between Weyburn and Estevan. The landscape is flat to gently undulating. Most land is cultivated, with limited hay-land and pasture existing mainly in low-lying 'pothole' areas. There are a few scattered ephemeral semi-wetlands (Figure 6.2.3).

Applying the classifications of Chapter 5, shelterbelt density for the selected test township is 'high', (25½ miles based on PFRA distribution records). This compares to 14½ shelterbelt miles recognizable on aerial photography dated 1949, 1962 and 1979, and field-surveyed in 1999. Of this distance, less than one mile (7%) has been removed without replacement between 1949 and 1999 (Figure 6.2.4). Approximately one-half of the existing shelterbelts were established (recognizable on aerial photographs) between 1962 and 1979. 40% have been planted since then. One-third of all shelterbelt mileage has been placed in the sections

Figure 6.2.3: Midale landscape. A line of willow has been planted parallel to the road in the photo centre (observed August, 1999).

encompassing, and lying immediately east of Midale (Sec.22 and Sec.23). Generally, the existing shelters appear to be healthy, although some of the more recently planted ones are rather widely spaced. Individual planting projects correspond variably to the distribution record (Table 6.2.3). For example, the numerous shelterbelts observed in section 23 can be traced to orders shipped in 1970, 1971, and 1976. The distribution history of other projects is not as clear.



Planted:

before 1949

1949-62

1962-79

1979-99

Removed/Deteriorated by:

1999

1962

1) Solid lines represent shelterbelts recognizable in the summer of 1999.
2) Broken lines represents shelter removed or deteriorated before 1999.

Figure 6.2.4: Shelterbelt placement in Twp.5, Rge.11, W.2. (Midale area), 1949-99.

Table 6.2.3: Field-type shelterbelt tree distribution record for Twp.5, Rge.11, W.2, 1949-98.

Sec.	Year	Type	App.Dist (mi)	Number	Species	Plt.Dist. (ft)	Calc.Dist. (mi)
	97	Field		700	Ash	6	0.80
	95	Field		25	Ash	6	0.03
	95	Field		625	Caragana	1	0.12
	94	Field		800	Ash	6	0.91
	94	Field		2,000	Caragana	1	0.38
	93	Field		1,700	Caragana	1	0.32
	93	Field		400	Siberian Larch	6	0.45
	92	Field		800	Ash	6	0.91
	92	Field		600	Acute Willow	6	0.68
	92	Field		2,400	Caragana	1	0.45
	92	Multi-use		2,000	Buffaloberry	3	1.14
	91	Field		1,000	Ash	6	1.14
	91	Field		1,000	Caragana	1	0.19
	90	Field		300	Laurel	6	0.34
	90	Field		8,000	Caragana	1	1.52
	90	Field		900	Buffaloberry	3	0.51
	87	Probable		50	Ash	6	0.06
	87	Probable		300	Siberian Elm	6	0.34
	87	Probable		100	Man. Maple	6	0.11
	87	Probable		200	Caragana	1	0.04
	83	Probable		125	Man. Maple	6	0.14
	83	Probable		1,300	Caragana	1	0.25
	81	Field		800	Buffaloberry	3	0.45
	81	Field		800	Chokecherry	3	0.45
17	79	Road	0.5	2,000	Caragana	1	0.38
				300	Poplar	6	0.34
34	78	Combined	1	5,200	Caragana	1	0.98
				650	Basfd. Willow	6	0.74
				900	Villosa Lilac	3	0.51
23	76	Field	0.5	600	Siberian Elm	6	0.68
				200	Basfd. Willow	6	0.23
25	75	Field	0.25	350	Siberian Elm	6	0.40
				1,400	Caragana	1	0.27
				250	N.W. Poplar	6	0.28
				10	Basfd. Willow	6	0.01
23	71	Rur. Hldg.	1.75	3,000	Russian Olive	6	3.41
				100	Siberian Elm	3	0.06
				200	Poplar	6	0.23
				200	Willow	6	0.23
				100	Col. Spruce	6	0.11
23	70	Rur. Hldg.	1.5	3,300	Siberian Elm	3	1.88
				500	Willow	4	0.38
				100	Scots Pine	6	0.11
23	69	Field	1	1,775	Siberian Elm	3	1.01
				500	Willow	4	0.38
32	55	Probable		375	Man. Maple	6	0.43
32	55	Probable		375	American Elm	6	0.43
32	55	Probable		1,500	Caragana	1	0.28
			Totals:	**50,810**			**25.48**

6.2.4 Interpretation

Although shelterbelts are well-distributed throughout the Midale region, overall 'mileage per township' density is fairly low. There are several reasons for this. Despite a relatively low soil moisture retention capability and usually a moisture deficiency at seeding time (Bootsma *et al*, 1992b), higher spring and summer precipitation likely lowers the risk of wind erosion, reducing the requirement for artificial moisture control. Additionally, permanent grazing cover protects many of the high erosion-risk places in the region's drier portions. This region has readily accepted conservation tillage practices and where these are utilized, there may not be much additional benefit to be realized from field shelterbelts.

Human and cultural influence may have played an important role in the case of the higher density plantings adjacent to Highway 39. Much of the activity there has been encouraged by a highly active local shelterbelt association, and a 'tradition' of conservation is now entrenched. Relatively high incomes in the area may have influenced shelterbelt adoption, in that the cost of establishing and maintaining field shelter for long-term gain is more easily borne.

Some notable shelterbelt attributes observed in the sample township have specific spatial causes. Local 'pot-hole' topography, impermeable soils, and adequate precipitation have allowed willow to be planted in an amount that is double the provincial average (approximately 12% of township shelterbelt mileage). The success of nearby reclamation 'wildlife' shelter projects at Estevan is the likely cause of the many buffaloberry observed here. A third noted feature is belt orientation that, in this case, has been influenced more by local topography and field layout than by the prevailing wind direction.

As there is no demonstrated dominant era of shelterbelt planting in the Midale region, historical factors are presumed to be less important in relation to spatial ones. The exception is the 1990s period, at which time, climatic and policy factors encouraged substantial planting throughout *all* of Saskatchewan. These determinants are discussed further in Chapter 7.

6.3 The Cadillac Focus Area

6.3.1 Area description

The Cadillac case area is defined as a part of south-west Saskatchewan bounded by 49°30′ and 50°30′ North latitude and 107° and 109° West longitude (Figure 6.3.1). Information recorded at the Swift Current Airport meteorological station, (Environment Canada ID 4028040), between 1949 and 1993 indicates that Cadillac region winters are particularly warm, with the January daily mean temperature maintained at -13.4°. For July, it is 18.3°.

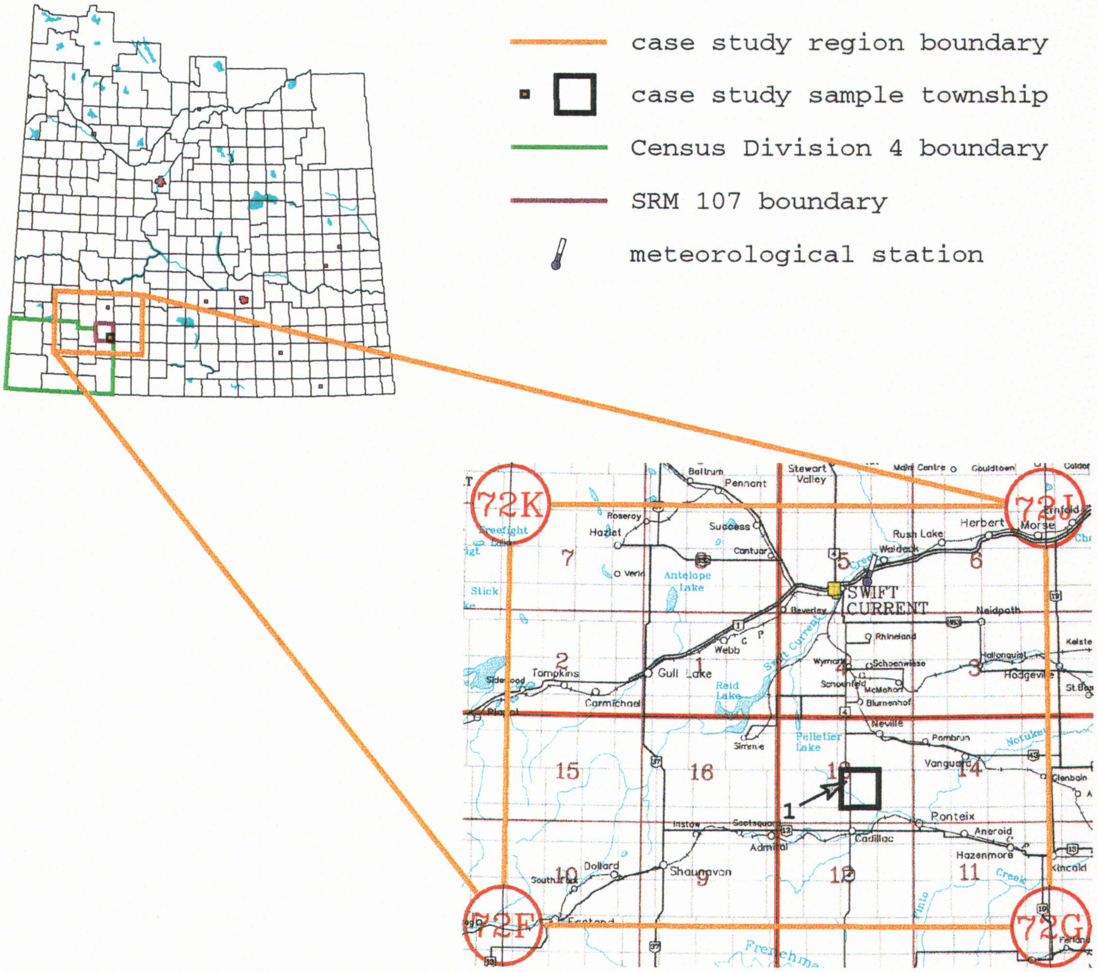


Figure 6.3.1: The Cadillac case study location. The numbered location (1) corresponds to Figure 6.3.4.

The most notable aspect of the long-term Swift Current temperature record is the markedly warmer late winter/early spring conditions of the late 1980s; an average of nearly eight degrees above the 44-year normal for the years 1984-88. Average Swift Current rainfall is 266 mm, and the normal snowfall, 121 mm. Long-term annual mean hourly wind speed is 22 km/h, approximately 7 km/h on average greater than velocities experienced in the other four case locales. In contrast to those, where wind speed is typically highest in spring and autumn, mid-winter is the windiest time in Swift Current. Based on 1953-93 statistics, the December and January mean hourly wind velocities are greater than 24 km/h and there is a 75% probability that wind speed will exceed 30 km/h on any given day at that time of year. Prevailing wind direction is west or south-west.

The Cadillac region is mostly mixed grassland with the south-west corner of the study area containing a portion of the rather physiographically unique Cypress Hills Upland. In both areas, natural vegetation is limited to a few undisturbed slopes and depressions. Substantial morphological variation characterizes this region, and as such, a wide range of soil types may be found. Brown to dark brown chernozems underlie most places, but isolated valley regosols have also formed. Texturally, soil tends to be silty to sandy in the hummocky and dune-marked north-west/central portion while glaciolacustrine clays and silty-loams, and till-based loams have developed elsewhere. The Cypress Hills feature diverse soil types depending upon local morphological composition. As might be expected, the region's many sandy areas are at the greatest risk of eolian erosion.

6.3.2 Land-use and agriculture

Despite the preponderance of marginal soil conditions in much of the Cadillac region, farming accounts for 98% of the land-use (Table 6.3.1). Most of the farmland at the highest risk of erosion is maintained as rangeland, representing one third of the total land area. The land-use, wind erosion risk and shelterbelt density overlay (Figure 6.3.2 and Table 6.3.2) shows several zones of moderate erosion hazard. Most of these are situated on the valley soil complexes. A number of the region's townships, including the sampled one near Cadillac, are classified as having 'High' shelterbelt density.

Cadillac agricultural production is generally similar to that of the Midale region, but year to year yields are highly variable. As in all cases, wheat is the principal crop, historically accounting for about three quarters of

Table 6.3.1: Cadillac land-use.

Land-Use Type	**Area (km^2)**	**% of Total**
Cropland	10,214	64.0
Rough Grazing	5,372	33.7
Improved Pasture	145	0.9
Water	116	0.7
Woodland, Non-Productive	38	0.2
Built-up Areas	30	0.2
Woodland, Productive	25	0.2
Barren	5	0.0
Recreation Areas	2	0.0
Quarries/Mines	1	0.0
Wetland	1	0.0
Total	**15,947**	**100.0**

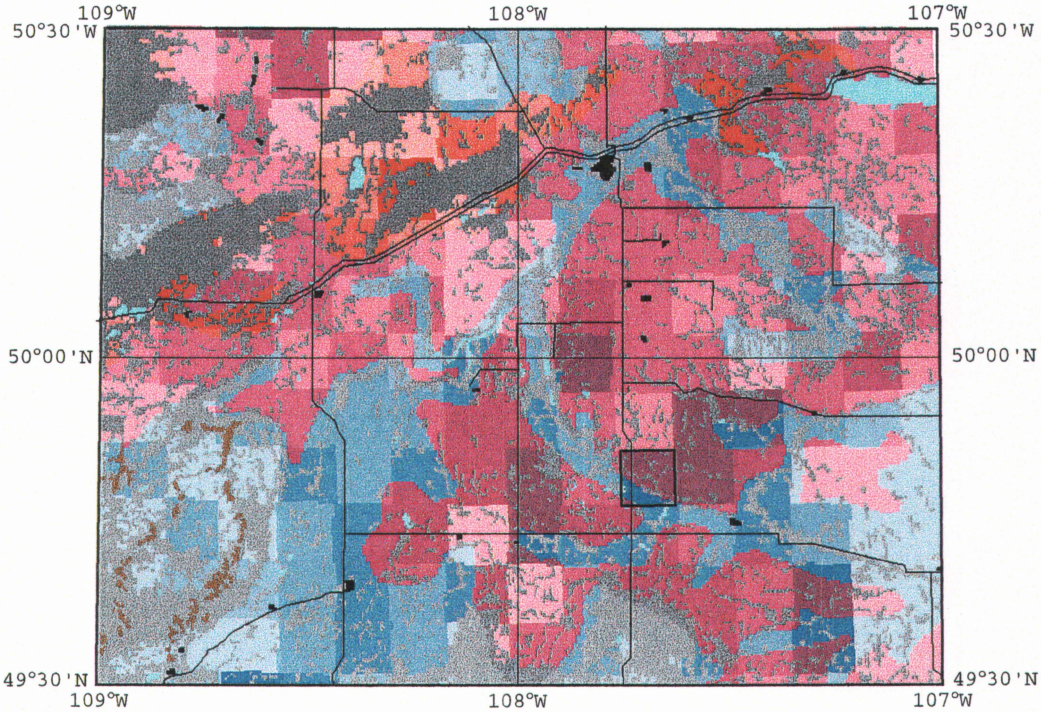


Figure 6.3.2: Cadillac land-use/ wind erosion risk/ shelterbelt density overlay. Refer to Table 6.3.2 (following page) for an explanation of the zones.

Table 6.3.2: Cadillac land-use, wind erosion risk and shelterbelt distribution zones. (refer to Figure 6.3.2)

Map zone	Area (km^2)	% total area	Zone description (Land-use, Wind Erosion Risk, Shelterbelt Density)*
	164	1.0	Cropland, Severe Risk, High Density
	185	1.2	Cropland, Severe Risk, Medium Density
	197	1.2	Cropland, Severe Risk, Low Density
	181	1.1	Cropland, Severe Risk, Negligible Density
	518	3.3	Cropland, High Risk, Very High Density
	1254	7.9	Cropland, High Risk, High Density
	2093	13.1	Cropland, High Risk, Medium Density
	1072	6.7	Cropland, High Risk, Low Density
	1015	6.4	Cropland, High Risk, Negligible Density
	154	1.0	Cropland, Moderate Risk, Very High Density
	747	4.7	Cropland, Moderate Risk, High Density
	1272	8.0	Cropland, Moderate Risk, Medium Density
	384	2.4	Cropland, Moderate Risk, Low Density
	948	6.0	Cropland, Moderate Risk, Negligible Density
	1115	7.0	Rough Grazing/Impr.Pasture, Severe Risk
	1877	11.8	Rough Grazing/Impr.Pasture, High Risk
	2501	15.7	Rough Grazing/Impr.Pasture, Moderate Risk
	153	1.0	Water/Wetland
	62	0.4	Woodland
	38	0.2	Built-up/Recreation/Mines and other Non-ag. Areas
	186		Unclassified

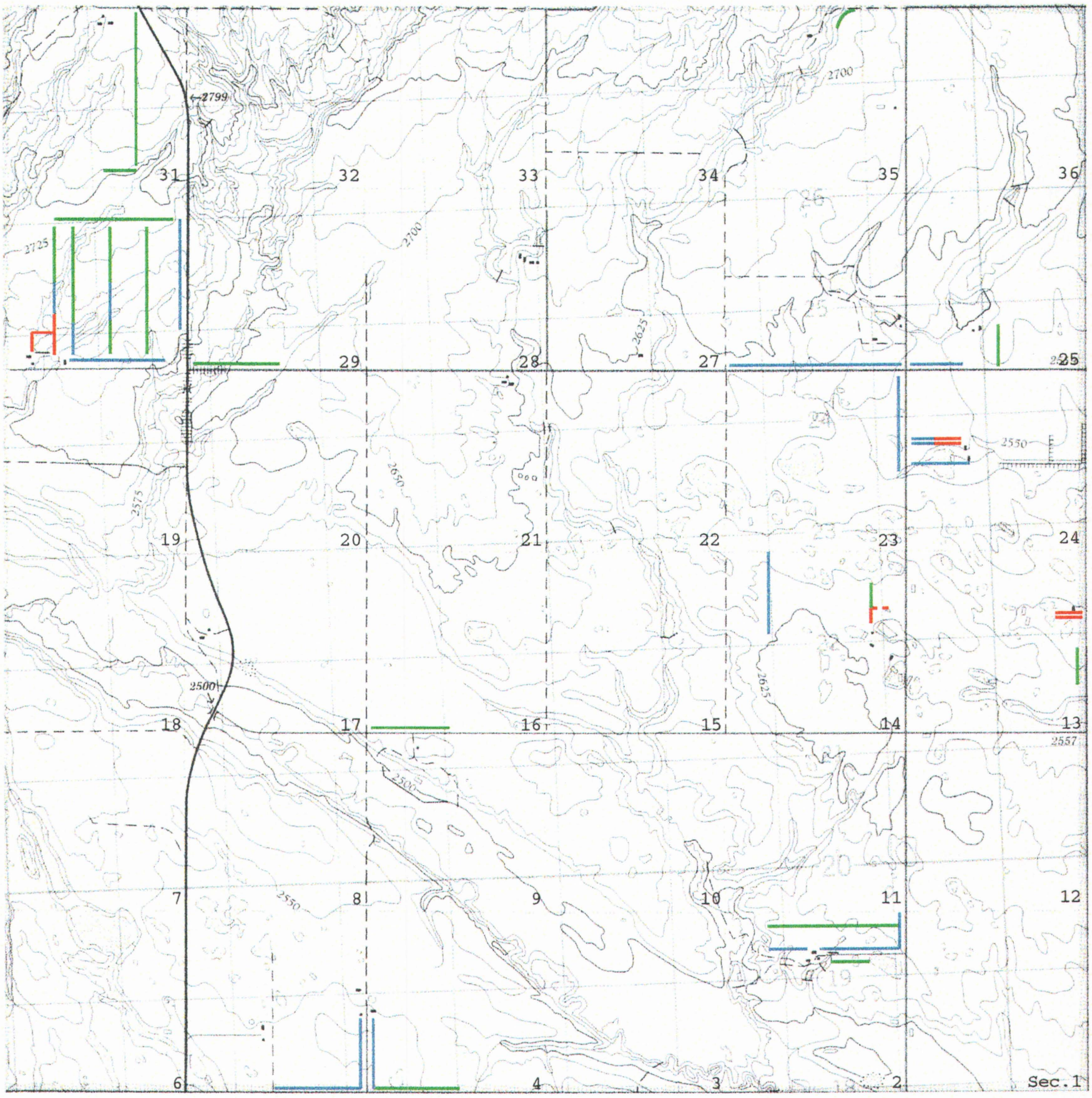
***NOTES:** Refer to table 6.2.2.

all land seeded. Tillage rates are high, and summerfallow still accounted for 40% of the cropland total in 1996. Each year, more land is broken and seeded.

6.3.3 Historical shelterbelt change

The township lying immediately north of the town of Cadillac (Twp.10, Rge.13. W.3) was chosen for local-scale study. This township features a dry, gently undulating morainal landscape that is geographically representative of much of the region. The distribution record shows the area received many field shelterbelt trees between 1949 and 1998, and the township is centrally located within a regional zone of dense shelterbelt concentration. Naturally-growing trees are rare.

Aerial photography dating from 1955 and 1981 was consulted and used in conjunction with 1999 ground survey results to produce a map of existing and removed shelterbelts (Figure 6.3.3). An apparent inconsistency between the distribution records and the mapping is evident. Since 1955, 15½ linear miles of field and road shelterbelt are visible in the photographic record and through field mapping. A negligible amount of this distance has been removed. Distribution records indicate sixty linear miles worth of trees (resulting in a 'very high' density rating) were shipped to locations within this township. This is a fourfold discrepancy, more than that for which usual error factors (mortality soon after establishment, deterioration between photographic flights,



Planted:

before 1955

1955-81

1981-99

Removed/Deteriorated by:

-------- 1999

1) Solid lines represent shelterbelts recognizable in the summer of 1999.
2) Broken lines represents shelter removed or deteriorated before 1999.

Figure 6.3.3: Shelterbelt placement for Twp. 10, Rge. 13, W.3. (Cadillac area), 1955-99

distance calculation assumptions, and so forth) would normally account. The distribution statistics indicate a high number of trees went to land locations (Sec.16, for example) for which no evidence of large scale planting exists (Table 6.3.3).

A large share (one third) of total measurable shelterbelt exists entirely within Sec.25. Much of the 5¼ miles planted here are related to a Saskatchewan Agriculture and Food (SAF) crop diversification orchard demonstration (Figure 6.3.4). The township's shelterbelts are reasonably healthy but some show evidence of serious neglect. It is expected that several existing shelters will deteriorate beyond usefulness in the near future.

6.3.4 Interpretation

The Cadillac region has historically possessed a high field shelterbelt adoption rate. The reasons for planting windbreaks here are fairly obvious. Chief among these are the highly erodible nature of many area soils and wind velocities that regularly exceed erosion thresholds. Additionally, relatively warm temperatures cause an increased risk of summer drought, and shelterbelts are useful in managing snow moisture distribution. The intensive mono-crop cultivation, tillage, and continued

Table 6.3.3: Field-type shelterbelt tree distribution record for Twp.10, Rge.13, W.3, 1949-98.

Sec.	Year	Type	App.Dist (mi)	Number	Species	Plt.Dist. (ft)	Calc.Dist. (mi)
	96	Field		1,500	Caragana	1	0.28
	96	Field		600	Chokecherry	3	0.34
	95	Field		3,750	Caragana	1	0.71
	94	Field		2,500	Caragana	1	0.47
	93	Field		400	Buffaloberry	3	0.23
	93	Field		400	Seabuckthorn	3	0.23
	91	Field		10,000	Caragana	1	1.89
	90	Field		10,000	Caragana	1	1.89
	88	Field		3,500	Ash	6	3.98
	88	Field		10,500	Caragana	1	1.99
	87	Field		3,525	Ash	6	4.01
	87	Field		10,575	Caragana	1	2.00
	86	Field		3,000	Caragana	1	0.57
	85	Road		3,000	Caragana	1	0.57
35	80	Field	12.5	50	Ash	6	0.06
				25	American Elm	6	0.03
				75	Siberian Elm	6	0.09
				67,900	Caragana	1	12.86
2	79	Road	0.25	600	Siberian Elm	6	0.68
31	79	Field	1	7,500	Caragana	1	1.42
				250	38P38 Poplar	6	0.28
2	74	Field	0.75	800	Siberian Elm	6	0.91
				100	Basfd. Willow	6	0.11
				100	White Spruce	6	0.11
2	73	Field	1	500	Siberian Elm	6	0.57
				200	Poplar	6	0.23
				100	Willow	6	0.11
26	73	Field	1	500	Siberian Elm	6	0.57
				500	Caragana	1	0.09
				500	Poplar	6	0.57
				500	Basfd. Willow	6	0.57
				100	Col. Spruce	6	0.11
2	72	Field	0.5	400	Siberian Elm	6	0.45
				30	Poplar	6	0.03
				200	Willow	6	0.23
23	72	Field	0.5	1,000	Siberian Elm	6	1.14
				2,500	Caragana	1	0.47
16	70	Field	2	3,600	Siberian Elm	3	2.05
2	69	Combined	1	100	Man. Maple	6	0.11
				100	Ash	6	0.11
				200	American Elm	6	0.23
				100	Siberian Elm	3	0.06
				4,000	Caragana	1	0.76
				100	Poplar	6	0.11
				200	Willow	4	0.15
25	69	Rur. Hldg.	0.75	2,000	Siberian Elm	3	1.14
26	69	Combined	1.5	2,000	Siberian Elm	3	1.14
				1,000	Caragana	1	0.19
				500	Poplar	6	0.57
16	68	Field	2	3,600	Siberian Elm	3	2.05
23	67	Field	1	500	American Elm	6	0.57
				500	Caragana	1	0.09

Table 6.3.3 continued

Sec.	Year	Type	(mi)	Number	Species	(ft)	(mi)
16	65	Field		1,325	Siberian Elm	3	0.75
16	65	Field		2,650	Caragana	1	0.50
16	65	Field		1,325	Poplar	6	1.51
16	65	Field		1,325	Willow	4	1.00
16	65	Field		100	Col. Spruce	6	0.11
16	62	Field		1,350	Poplar	6	1.53
16	62	Field		1,325	Willow	4	1.00
16	56	Probable		2,000	Acute Willow	4	1.52
16	56	Probable		2,000	Laurel	6	2.27
			Totals:	**179,580**			**60.38**

Figure 6.3.4: Major shelterbelt project in Sec.25, Twp.10, Rge.13, W.3. (observed July, 1999)

breaking of marginal land further validates the use of soil conservation measures. Furthermore, tree propagation is affected by the often-harsh conditions in the same way agriculture is. Aneroid, an original 1930s PFRA shelterbelt test site located here, was considered a failure compared to the more successful Conquest project. The region's physiographic nature was a primary reason for this. Natural trees are very scarce.

This region, to a greater extent than the other cases, has likely had more social and historical-contextual influence to its shelterbelt use. Much of the area was particularly vulnerable during the 1930s droughts and many farms were abandoned. Farm traditions initiated during that period, including the planting of shelter to offset the results of 'necessary' summerfallowing, are well-entrenched. The uniform cultural composition (predominantly Mennonite) in a number of places showing substantial shelter development has probably also played a role.

A large number of Cadillac region shelterbelts were planted in the mid-1960s to mid-1970s. One possible cause for this is droughts occurring in 1958 and 1961 that resulted in dramatically lower crop production. The 1960s were also a period of significant cropland expansion and it is likely that shelterbelts were planted on former rangeland as it was broken.

Within the sample township, two thirds of shelterbelt mileage (from the distribution record) were planted with either caragana or siberian elm. Both are highly drought-tolerant and the latter is particularly suited to south-west Saskatchewan (PFRA, 1993). Conversely, conifers, willows and 'showy' species have been requested in relatively small numbers. However, the discrepancy between shelterbelt density calculated from PFRA records and ground-surveyed mileage is problematic. In most sections, observed shelterbelts do not correspond to plantings suggested by the tree shipment history. Two main scenarios are possible. Because much of the discordance is connected to applicants residing in Sec. 16 and 35, it might be argued that incorrect land locations were recorded during initial PFRA application processing. A second reasoning suggests that for either applicant, the 'home quarter' was properly annotated but, the trees shipped there were planted elsewhere. Notwithstanding the measurement discrepancy, a large number of readily identifiable, mature shelterbelts exist in neighbouring townships and the error does not subtract from the overall value of the distribution mapping for the region.

6.4 The Davidson-Bladworth Focus Area

6.4.1 Area description

The Davidson-Bladworth case site is situated within the moist-mixed grassland zone of south-central Saskatchewan. The region spans the area from the Last Mountain and Little Manitou lakes in the east to the South Saskatchewan River in the west. 105° and 107° West are the meridional boundaries, and 51° and 52° North latitude define the southern and northern extents (Figure 6.4.1). Two meteorological stations, Davidson (ID4012120) and Outlook PFRA (ID4055736) were used to summarize the Davidson-Bladworth climate. Year-round temperatures were notably higher here for the 1989-92 interval (specifically 1.9° above the usual 1.9°). This differs from other places where 1984-88 was the warmest period. From 1949 to 1992, the January daily mean was -18.1° and that for July, 18.1°. The Davidson-Bladworth region is the driest of the five cases. Weyburn and Swift Current each receive slightly less snow and rainfall respectively, but overall total annual mean precipitation for Davidson/Outlook is a meager 365 mm; approximately 30 mm less than the more southern locales. The 15 km/h mean annual wind speed recorded at Outlook is typical for much of southern Saskatchewan. Very high winds

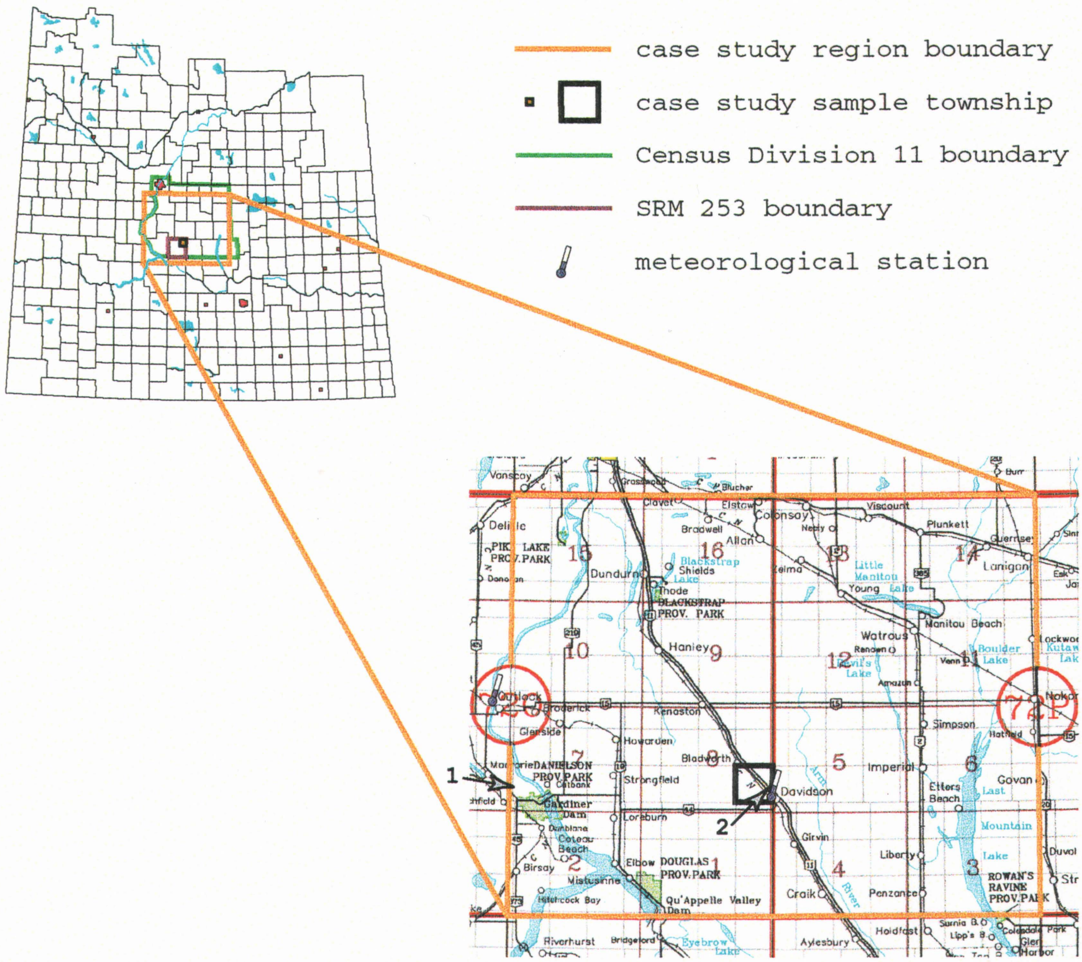


Figure 6.4.1: The Davidson-Bladworth case study location. The numbered points correspond to figures 6.4.2 (1) and 6.4.5 (2).

(above 50 km/h) are infrequent, but only one out of every 200 hours between 1963 and 1992 was calm. Wind usually blows from the north-west or south-east.

The moist mixed grassland that covers most of the Davidson-Bladworth region is divided into two main zones: poorly stabilized sandy strips adjacent to the South

Saskatchewan River, and morainal/glaciolacustrine uplands and plains underlying the remainder. The dune and glaciolacustrine morphology of the former has resulted in several Regosolic tracts. Dark brown to black Chernozems are dominant in much of the rest, but there are numerous areas of varied soil development where Solonetzics and saline Regosols are observed. The sandy soils near the South Saskatchewan River are at the greatest risk of eolian erosion. Other 'severe risk' places include the Arm River valley, the Allan Hills, the Elbow district and the saline Regosolic zone extending north from Last Mountain Lake through Lanigan. Much of the remainder is at moderate risk (Figure 6.4.2).

6.4.2 Land-use and agriculture

Like the other regions, Davidson-Bladworth is primarily cultivated. Despite the presence of large tracts of marginal land, proportionately less of the total area (approximately 23%) is rangeland or pasture (Table 6.4.1). Most of this is located in places most susceptible to erosion. Sizable portions of these vulnerable areas are wooded (Figure 6.4.3 and Table 6.4.2). On cultivated land, the proportion seeded with wheat has recently declined to one half, supplanted largely by oilseeds. Summerfallowing

Figure 6.4.2: Well-sheltered land near Lake Diefenbaker (observed July, 1999). This land is classified as being at moderate risk of wind erosion.

was traditionally practiced to a greater extent, but conservation tillage methods are gaining in popularity. Notably, past mono-crop reliance has had a cost of sustainment attached. Of the five studied, the Davidson-Bladworth region has the highest rate of fertilizer, herbicide and irrigation use.

Table 6.4.1: Davidson-Bladworth land-use.

Land-Use Type	**Area (km^2)**	**% of Total**
Cropland	10,978	70.7
Rough Grazing	3,375	21.8
Water	520	3.4
Woodland, Non-Productive	414	2.7
Improved Pasture	132	0.9
Built-up Areas	40	0.3
Wetland	28	0.2
Barren	12	0.1
Woodland, Productive	7	0.0
Quarries/Mines	6	0.0
Recreation Areas	5	0.0
Total	**15,517**	**100.0**

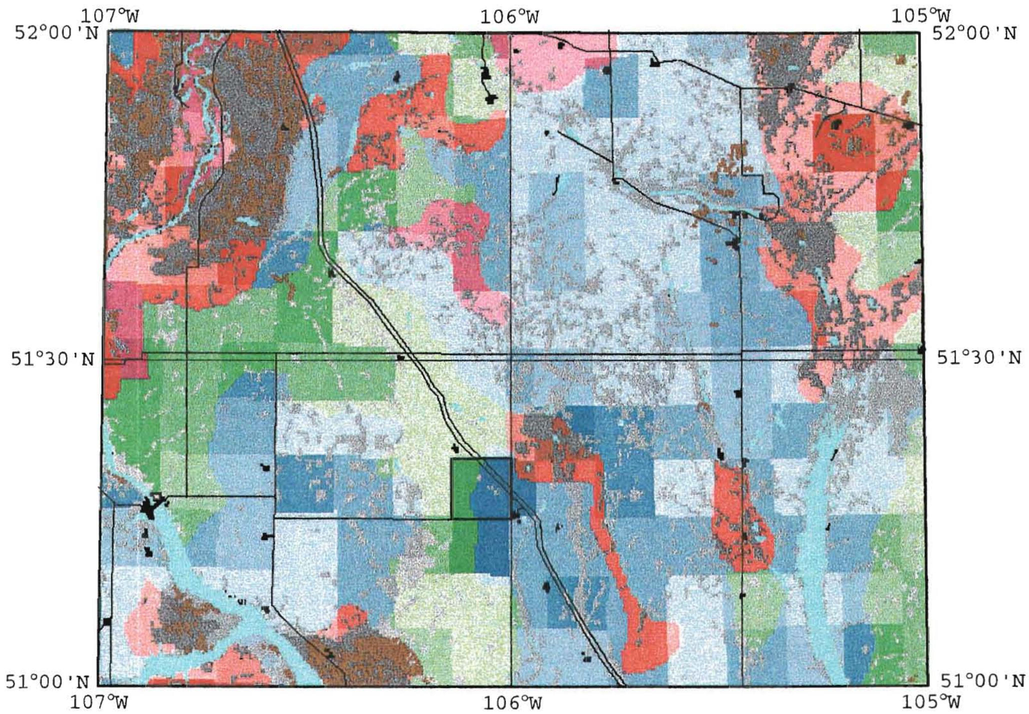


Figure 6.4.3: Davidson-Bladworth land-use/wind erosion risk/shelterbelt density overlay. Refer to Table 6.4.2 (following page) for an explanation of the zones.

Table 6.4.2: Davidson-Bladworth landuse, wind erosion risk and shelterbelt distribution zones. (refer to Figure 6.4.3)

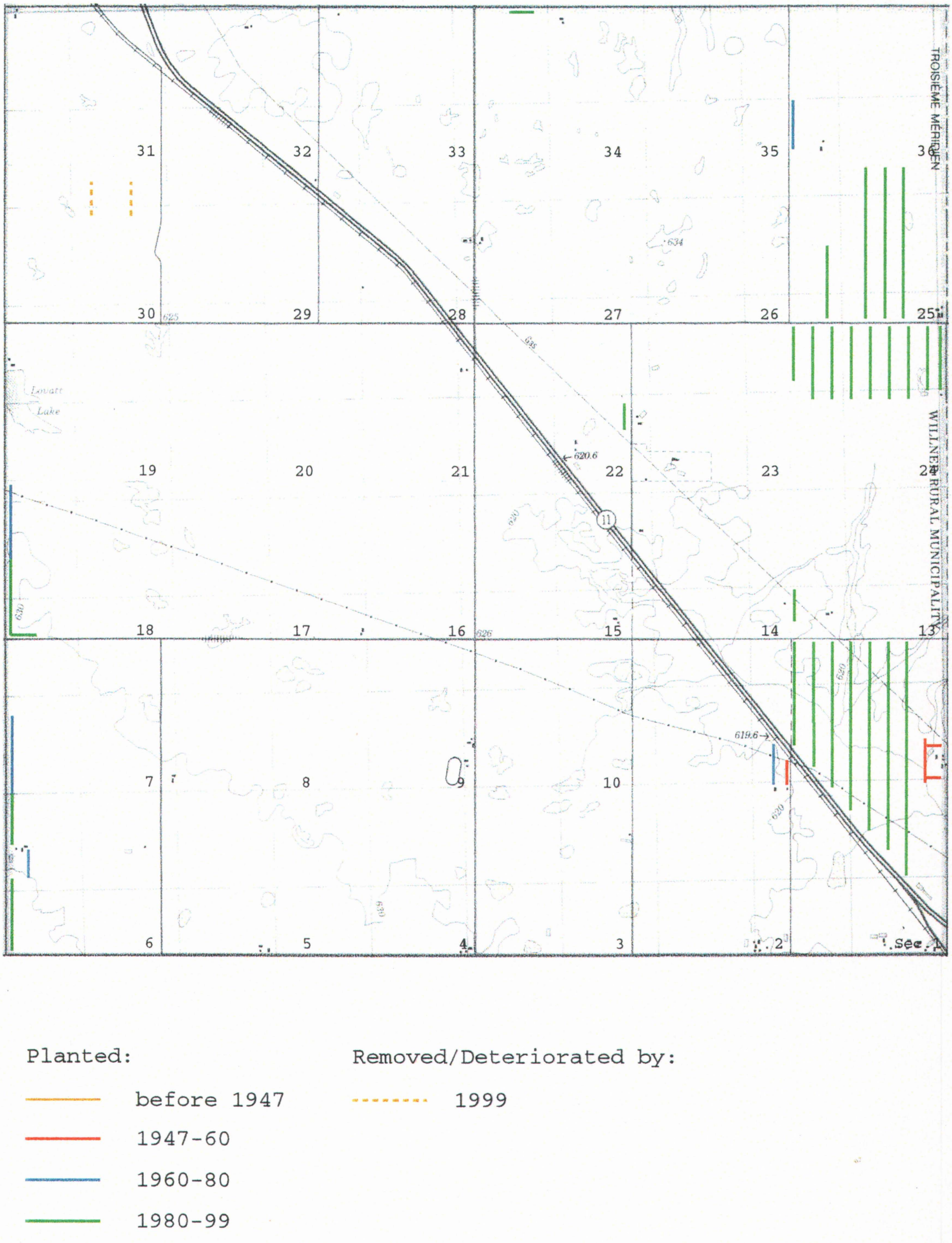
Map zone	Area (km^2)	% total area	Zone description (Land-use, Wind Erosion Risk, Shelterbelt Density)*
	61	0.4	Cropland, Severe Risk, Very High Density
	277	1.8	Cropland, Severe Risk, High Density
	492	3.2	Cropland, Severe Risk, Medium Density
	304	2.0	Cropland, Severe Risk, Low Density
	530	3.4	Cropland, Severe Risk, Negligible Density
	3	0.0	Cropland, High Risk, Very High Density
	49	0.3	Cropland, High Risk, High Density
	149	1.0	Cropland, High Risk, Medium Density
	66	0.4	Cropland, High Risk, Low Density
	190	1.2	Cropland, High Risk, Negligible Density
	166	1.1	Cropland, Moderate Risk, Very High Density
	478	3.1	Cropland, Moderate Risk, High Density
	1785	11.5	Cropland, Moderate Risk, Medium Density
	1120	7.2	Cropland, Moderate Risk, Low Density
	2434	15.7	Cropland, Moderate Risk, Negligible Density
	80	0.5	Cropland, Low Risk, Very High Density
	480	3.1	Cropland, Low Risk, High Density
	770	5.0	Cropland, Low Risk, Medium Density
	465	3.0	Cropland, Low Risk, Low Density
	1045	6.8	Cropland, Low Risk, Negligible Density
	1315	8.5	Rough Grazing/Impr.Pasture, Severe Risk
	123	0.8	Rough Grazing/Impr.Pasture, High Risk
	1628	10.5	Rough Grazing/Impr.Pasture, Moderate Risk
	427	2.8	Rough Grazing/Impr.Pasture, Low Risk
	548	3.5	Water/Wetland
	418	2.7	Woodland
	62	0.4	Built-up/Recreation/Mines and other Non-ag. Areas
	427		Unclassified

***NOTE:** refer to figure 6.2.2

6.4.3 Historical shelterbelt change

The township lying directly between the towns of Davidson and Bladworth, bisected by Provincial Highway 11, (Twp.27, Rge.1, W.3) has been selected for shelterbelt mapping. This township is one within a 'very high' shelterbelt density cluster located in a zone of low to moderate wind erosion risk. The landscape is a gently undulating morainal plain, strewn intermittently with wetland potholes and aspen bluffs.

The majority of shelterbelt plantings that have given this township its 'very high density' rating represent two principal efforts occurring around and after 1980 in sections 1/12 and 24/25 (Figure 6.4.4). Most shelterbelt trees are well established, but some, especially those furthest west, are in poorer health (Figure 6.4.5). In total, twenty linear shelterbelt miles are visible across the entire township (one half the distance calculated from the distribution records – Table 6.4.3). The concentrated plantings are located in the eastern half; a notably more open landscape than the bluff-dotted western portion. Almost all of the area's shelterbelts are orientated north-south, reflecting the prevailing west-east wind direction. No belts planted during the study period have been removed.



1) Solid lines represent shelterbelts recognizable in the summer of 1999.
2) Broken lines represents shelter removed or deteriorated before 1999.

Figure 6.4.4: Shelterbelt placement for Twp. 27, Rge. 1, W.3. (Davidson-Bladworth area), 1947-99

Figure 6.4.5: Porous shelterbelt near Davidson, July, 1999.

Table 6.4.3: Field-type shelterbelt tree distribution record for Twp.27, Rge.1, W.3, 1949-98.

Sec.	Year	Type	App.Dist (mi)	Number	Species	Plt.Dist. (ft)	Calc.Dist. (mi)
	97	Field		7,500	Caragana	1	1.42
	92	Field		5,000	Caragana	1	0.95
	90	Field		500	Ash	6	0.57
	90	Field		5,000	Caragana	1	0.95
	89	Field		9,625	Ash	6	10.94
	89	Field		300	Acute Willow	6	0.34
	89	Field		15,175	Caragana	1	2.87
	89	Field		1,100	Chokecherry	3	0.63
	89	Field		350	Siberian Larch	6	0.40
	88	Field		6,200	Ash	6	7.05
	88	Field		18,500	Caragana	1	3.50
	87	Field		4,000	Ash	6	4.55
	87	Field		5,300	Caragana	1	1.00
	87	Field		900	Villosa Lilac	3	0.51
	86	Field		4,800	Ash	6	5.45
	86	Field		9,850	Caragana	1	1.87
	81	Field		525	Ash	6	0.60
	81	Field		5,700	Caragana	1	1.08
24	59	Probable		2,400	Caragana	1	0.45
			Totals:	**102,725**			**45.11**

6.4.4 Interpretation

Interpretation of shelterbelt placement patterns in the Davidson-Bladworth case region is difficult as shelterbelt densities vary from 'very high' to 'low', over short distances, without obvious cause. To a certain extent, the variation is explained by the region's complex physiography. Soil susceptibility to erosion deviates greatly across the area and, generally, the highest shelterbelt densities are located in places at greatest risk. An important factor is the long-time PFRA presence at nearby Outlook-Conquest, which has undoubtedly encouraged Davidson-Bladworth area landowners to adopt field shelterbelts.

Other influences are not as clear. Despite its moist-mixed ecological classification, the region is the driest of those studied (undoubtedly the cause of the low crop production). This would likely be a factor in the favour of shelterbelts at the local level. However, winds and temperatures are both moderate, and much of the region provides a suitable habitat for natural tree growth. Judicious use of land has probably had more effect on shelterbelt use. The areas most vulnerable to eolian erosion are either maintained as grazing land or have been left wooded. Many area producers may not perceive a pressing need for further artificial protection.

The sample township shelterbelt placement pattern is representative of much of the windbreak planting within the region as a whole. In this township, almost all field sheltering trees have been planted in two engineered 'projects', predominantly in the late 1980s. The map does not show the more dispersed apportioning seen in places where environmental conditions are more obvious determinants of shelterbelt use. It should be noted that the adjacent township lying immediately to the east of the sample one similarly features high density multiple-belt projects. These were planted in conjunction with a major Saskatchewan Wildlife shelterbelt initiative.

6.5 The Wilkie-Unity Focus Area

6.5.1 Area description

The Wilkie-Unity study region is in west-central Saskatchewan, extending from 108°W, just east of North Battleford, to the Saskatchewan-Alberta border at 110°W. The south and north boundaries are 52° and 53° North latitude respectively (Figure 6.5.1). The North Battleford Airport (ID4045600) meteorological station's record shows

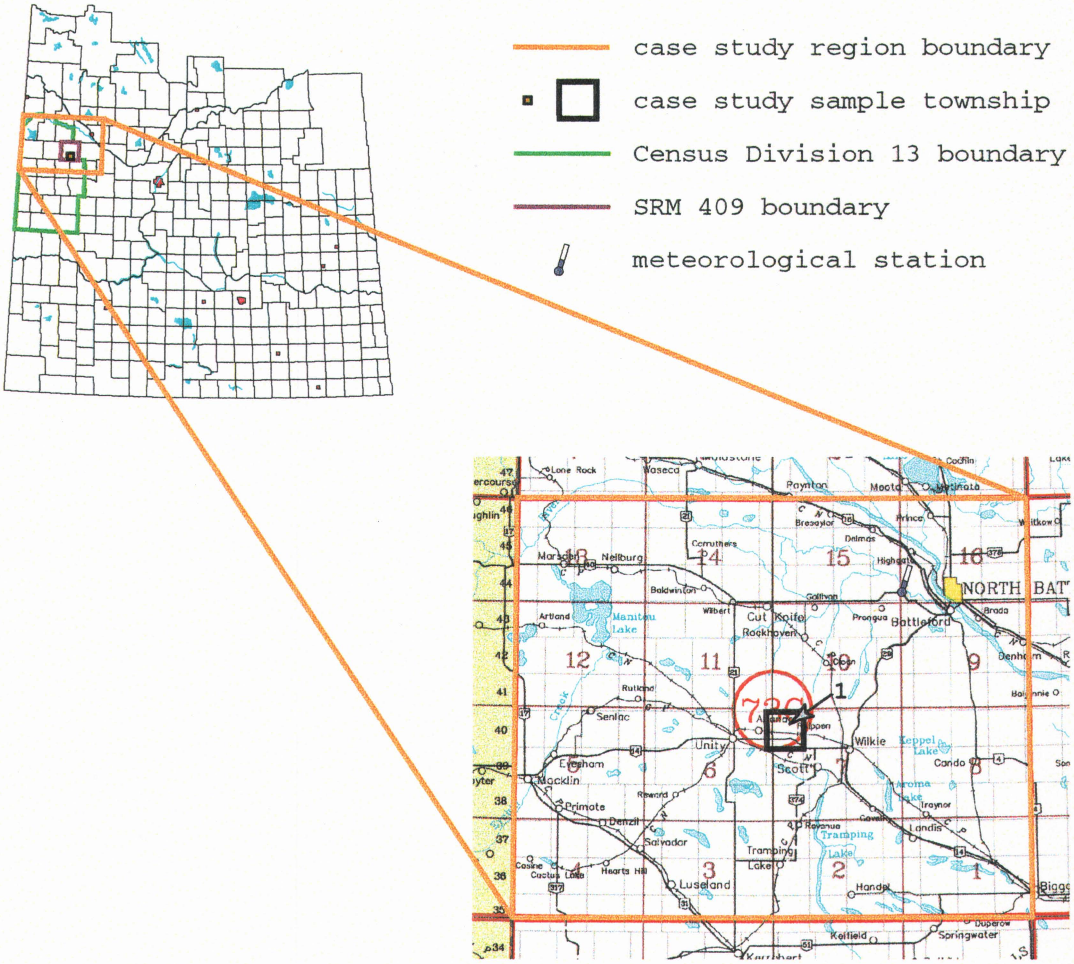


Figure 6.5.1: The Wilkie-Unity case study location. The numbered point (1) corresponds to figure 6.5.4.

the Wilkie-Unity year-round climate is slightly more moderate than that of Davidson/Outlook. The normal January daily mean temperature is -17.6°, and that for July, 18.0°. The late 1980s fluctuation was not as great as in the more southerly places, with the 1984-88 average annual mean temperature only 1° greater than the 1.8° norm. North Battleford is the second driest of the five case sites, with a long-term 267 mm of rain and 112 mm of snow falling yearly. During the warm 1984-88 period, North Battleford received its greatest average annual precipitation; a five year annual mean of 438 mm. North Battleford winds blow at a typical annual average of 15 km/h, most often from the north-west or south-east. Nearly ten percent of hours for which wind speed was recorded were calm.

The Wilkie-Unity study area straddles the transition zone between moist mixed grassland and aspen parkland. The western half is primarily morainal upland while glaciolacustrine/morainal plain morphology dominates the east. Wilkie-Unity soils are typically dark brown Chernozems in the grassland south, grading to black Chernozemic in the parkland north. Dune-derived Regosols and valley complex Regosols are also present. Most soils are loamy in texture, except for those associated with dunes, and a small band of clayey soils south of Unity. As might be expected, the sandy areas are at the severest risk of eolian erosion.

6.5.2 Land-use and agriculture

Due to the presence of marginal soils and unsuitable topography in a number of places, proportionately less land is cultivated. Still, nearly two-thirds of the region has been broken, and an additional 22% is used as rangeland/pasture (Table 6.5.1). The share of forested land is comparatively greater, and nearly 600 km^2 is either water or wetland. From the land-use/wind erosion risk/shelterbelt density map, (Figure 6.5.2 and Table 6.5.2), it is obvious that much of the cropland is at low risk of wind erosion.

Due to the more moderate climatological nature of the Wilkie-Unity region, agricultural yields are substantially greater and less temporally variable than in the southern cases. The mean wheat yield surpasses 60 bushels/ha and canola returns are highest of all examples at an average 57 bu/ha, the latter crop accounting for approximately 13% of seeded land in 1996. Contrary to the other cases, Wilkie-Unity has shown a trend away from diversification. Miscellaneous crops, forage production, and livestock have all seen a decline in the division of farm activity. However, Wilkie-Unity producers are adopting conservation tillage practices in greater numbers. Nearly 30% of all seeded hectares are currently 'zero-till'. The richest mean farming incomes of the five cases are achieved in the Wilkie-Unity area. Farms in SRM 409 received over $40,500 net income in 1996 and per-farm value is substantial at an average of nearly $700,000 in 1996.

Table 6.5.1: Wilkie-unity land-use.

Land-Use Type	**Area (km^2)**	**% of Total**
Cropland	9,181	60.6
Rough Grazing	3,330	22.0
Woodland, Non-Productive	1,602	10.6
Water	524	3.5
Woodland, Productive	327	2.2
Wetland	64	0.4
Improved Pasture	56	0.4
Built-up Areas	38	0.3
Barren	15	0.1
Intensive Cultivation	3	0.0
Recreation Areas	2	0.0
Quarries/Mines	2	0.0
Total	**15,144**	**100.1**

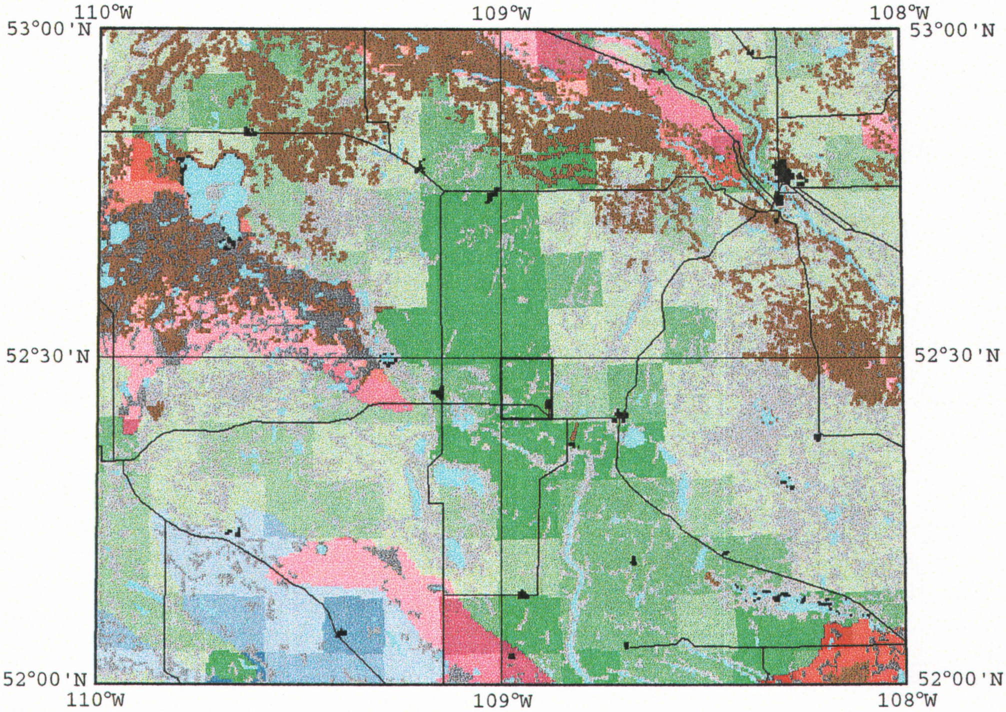


Figure 6.5.2: Wilkie-Unity land-use/wind erosion risk/shelterbelt density overlay. Refer to Table 6.5.2 (following page) for an explanation of the zones.

Table 6.5.2: Wilkie-Unity landuse, wind erosion risk and shelterbelt distribution zones. (refer to Figure 6.5.2)

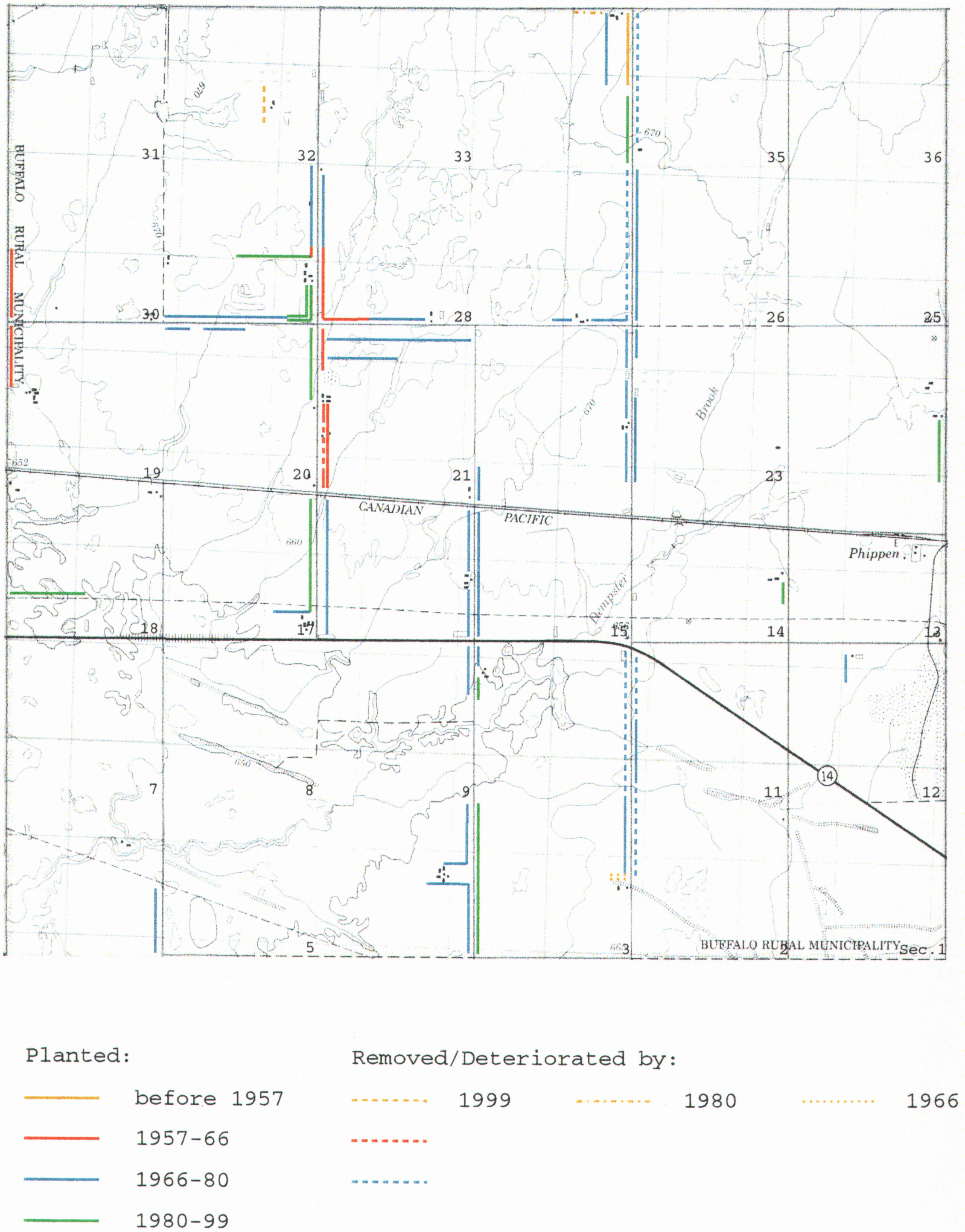
Map zone	**Area (km^2)**	**% total area**	**Zone description (Land-use, Wind Erosion Risk, Shelterbelt Density)***
	23	0.2	Cropland, Severe Risk, High Density
	128	0.8	Cropland, Severe Risk, Medium Density
	73	0.5	Cropland, Severe Risk, Low Density
	89	0.6	Cropland, Severe Risk, Negligible Density
	5	0.0	Cropland, High Risk, High Density
	185	1.2	Cropland, High Risk, Medium Density
	164	1.1	Cropland, High Risk, Low Density
	477	3.2	Cropland, High Risk, Negligible Density
	12	0.1	Cropland, Moderate Risk, High Density
	94	0.6	Cropland, Moderate Risk, Medium Density
	229	1.5	Cropland, Moderate Risk, Low Density
	442	2.9	Cropland, Moderate Risk, Negligible Density
	1395	9.2	Cropland, Low Risk, High Density
	1482	9.8	Cropland, Low Risk, Medium Density
	1575	10.4	Cropland, Low Risk, Low Density
	2791	18.5	Cropland, Low Risk, Negligible Density
	327	2.2	Rough Grazing/Impr.Pasture, Severe Risk
	199	1.3	Rough Grazing/Impr.Pasture, High Risk
	138	0.9	Rough Grazing/Impr.Pasture, Moderate Risk
	2719	18.0	Rough Grazing/Impr.Pasture, Low Risk
	588	3.9	Water/Wetland
	1930	12.8	Woodland
	57	0.4	Built-up/Recreation/Mines and other Non-ag. Areas
			Unclassified

***NOTE:** Refer to Table 6.2.2.

6.5.3 Historical shelterbelt change

Centrally situated within the Wilkie-Unity region is a band of high density shelterbelt plantings extending from the town of Cut Knife south towards the Tramping Lake area. These lie in an area of prosperous farmland at a low risk of wind erosion. It is here that a sample township (Twp.40, Rge.21, W.3) was chosen for further study. This township is situated midway between Wilkie and Unity on a gently undulating plain characterized by several scattered aspen bluffs and sloughs.

In contrast to other sample locations, the calculated shelterbelt distance closely matches the measured linear distance. Three sets of aerial photographs, dated 1957, 1966 and 1980 were used in concert with 1999 ground surveying to chart the shelterbelt history. A total of 27¼ shelterbelt miles have been planted at various times after 1957 (Figure 6.5.3). This compares to a calculated 24½ miles worth of trees shipped to locations in the township since 1954. Two-thirds of the shelterbelts were established between 1966 and 1980 (as observed on the air photos) and this is supported by the distribution record (Table 6.5.3). A relatively large amount of shelter was either removed or, had deteriorated by 1999; 18% of the total, and 22% of



1) Solid lines represent shelterbelts recognizable in the summer of 1999.
2) Broken lines represents shelter removed or deteriorated before 1999.

Figure 6.5.3: Shelterbelt placement for Twp.40, Rge.21, W.3. (Wilkie-Unity area), 1957-99.

Table 6.5.3: Field-type shelterbelt tree distribution record for Twp.40, Rge.21, W.2, 1949-98.

Sec.	Year	Type	App.Dist (mi)	Number	Species	Plt.Dist. (ft)	Calc.Dist. (mi)
	92	Field		800	Ash	6	0.91
	92	Field		800	Chokecherry	3	0.45
	91	Field		800	Ash	6	0.91
	90	Field		800	Ash	6	0.91
	88	Field		900	Ash	6	1.02
	88	Field		1,775	Caragana	1	0.34
	84	Field		1,000	Caragana	1	0.19
	82	Field		250	Siberian Elm	6	0.28
6	80	Road	1	900	Ash	6	1.02
6	77	Road	1.25	1,800	Siberian Elm	6	2.05
				50	White Spruce	10	0.09
14	73	Rur. Hldg.	1	500	Siberian Elm	6	0.57
				1,500	Caragana	1	0.28
16	71	Rur. Hldg.	0.5	2,650	Caragana	1	0.50
17	71	Field	1.25	25	Siberian Elm	3	0.01
				6,600	Caragana	1	1.25
				50	Poplar	6	0.06
				25	Russian Olive	6	0.03
				30	Scots Pine	6	0.03
4	70	Rur. Hldg.	1	5,300	Caragana	1	1.00
17	70	Road	1	50	Villosa Lilac	3	0.03
				200	Honeysuckle	3	0.11
				5,550	Caragana	1	1.05
				75	Poplar	6	0.09
				40	Col. Spruce	6	0.05
16	67	Field	0.75	4,000	Caragana	1	0.76
7	65	Probable		2,600	Caragana	1	0.49
16	65	Field		2,650	Caragana	1	0.50
4	63	Field		100	Man. Maple	6	0.11
4	63	Field		75	Ash	6	0.09
4	63	Field		75	American Elm	6	0.09
4	63	Field		900	Caragana	1	0.17
6	62	Field	1.5	250	Siberian Elm	3	0.14
				5,300	Caragana	1	1.00
4	61	Field/Farm		275	Man. Maple	6	0.31
4	61	Field/Farm		275	Ash	6	0.31
4	61	Field/Farm		275	American Elm	6	0.31
4	61	Field/Farm		1,300	Caragana	1	0.25
4	61	Field/Farm		75	Dunlop Poplar	6	0.09
4	61	Field/Farm		30	White Spruce	6	0.03
4	59	Field		5,300	Caragana	1	1.00
17	57	Probable		575	Man. Maple	6	0.65
17	57	Probable		1,175	American Elm	6	1.34
17	57	Probable		6,025	Caragana	1	1.14
17	57	Probable		575	Dunlop Poplar	6	0.65
7	54	Probable		150	Man. Maple	6	0.17
7	54	Probable		525	American Elm	6	0.60
7	54	Probable		3,750	Caragana	1	0.71
7	54	Probable		50	Col. Spruce	6	0.06
7	54	Probable		50	White Spruce	6	0.06
7	54	Probable		100	Scots Pine	6	0.11
			Totals:	**68,925**			**24.39**

those planted between 1966 and 1980. Most shelterbelts are in excellent health, although one section, in particular, showed evidence of severe livestock-induced damage (Figure 6.5.5).

Figure 6.5.4: Livestock-damaged shelterbelt in the Wilkie-Unity district (observed August, 1999). Most other area shelters are notably healthy.

6.5.4 Interpretation

Except for the late 1980s/early 1990s interval, Wilkie-Unity shelterbelt tree orders have been reasonably consistent throughout the study period. At the local case level, caragana is the dominant species planted, but other types more suited to a moderate environment, including poplar, are observed. Shelterbelt orientation reflects the predominantly west-east prevailing winds. Although a comparatively large proportion of shelter has been removed, almost all of this had been situated immediately across a road from duplicate windbreaks. This loss of trees will have had minimal impact on the quality of field protection.

The reasons for the concentration of shelterbelts in the centre of the larger Wilkie-Unity region are not altogether clear. The parkland ecology provides ideal habitat for a number of natural bluffs and the gently rolling farmland on mostly loamy soils is not at serious risk of erosion. Several soil conservation methods are practiced and this almost certainly accounts for the fact that no recent shelterbelts have been added to the sample township. The area climate is moderate, but its fairly dry nature, coupled with strong springtime winds may have influenced shelterbelt adoption.

If environmental risks (such as the risk of wind erosion) are less severe, 'cultural' factors have a greater influence in the decision to plant windbreaks. For example, when new shelterbelts are being planned, costs including windbreak maintenance and loss of productive land must be compared to the potential agricultural gain. In this region, higher farm incomes may allow producers greater latitude in exploring conservation techniques when there is a potential for loss. Other human influences are probable. For example, this region has likely been subject to a 'spill-off' effect, similar to that in the Davidson-Bladworth case, whereby initial shelterbelt projects have influenced other district landowners to follow suit. This phenomenon has been observed in other locations and is a major determinant of shelterbelt use. The Scott experimental station, located here, has undoubtedly enhanced local adoption of several conservation farming techniques including field shelter. However, further investigation is required in order to fully explain shelterbelt use in this region.

6.6 The Nipawin Focus Area

6.6.1 Area description

The final case, the Nipawin region, is the northernmost place studied. Much of the area is situated on the agricultural fringe of north-eastern Saskatchewan. It is spatially bounded on the south and north by 52°,30′ and 53°,30′ North latitudes and on the east and west by the 103rd and 105th meridians (Figure 6.6.1).

Climate data recorded between 1949 and 1993 at two Nipawin stations, Environment Canada ID4075518 (Nipawin Airport), and ID4075520 (Nipawin2), reveal that Nipawin is the coolest of the case sites, achieving, on average, an annual mean of 0.6°. The normal January daily mean temperature is -20.3, rising to an average daily mean of 18° in July; giving Nipawin summer warmth equivalent to that at North Battleford. Average annual temperatures have been comparatively less variable over the long-term, with a standard deviation of only 0.5°. Nipawin is the only site of the five analyzed to record a long-term average annual precipitation total exceeding 400 mm. Average annual rainfall from 1954-92 was 318 mm, with an additional 120 mm of yearly snow. Notably, other stations in the region have recorded higher snowfall totals (in the range of 140 mm).

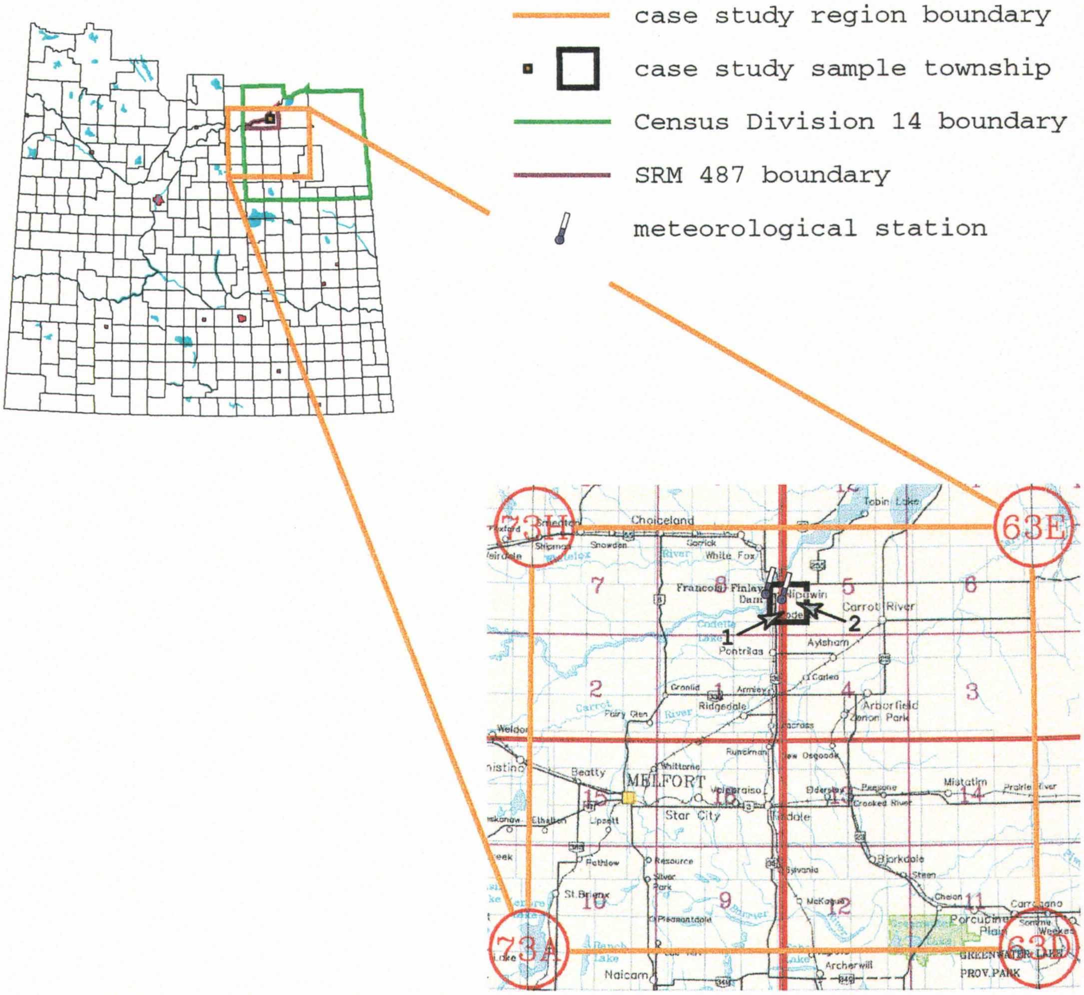


Figure 6.6.1: Nipawin case study location. The numbered points correspond to figures 6.6.4 (1) and 6.6.5 (2).

Nipawin summers are relatively calm. Average hourly wind speed is less than 12 km/h for both July and August. The mean annual wind speed of 13.5 km/h is lowest of the cases. High winds (above 30 km/h) are rare. There is no overwhelming prevailing wind direction, but winds from the south through north-west are the most common.

The Nipawin case region is in the heart of the Boreal Transition ecoregion and approximately 35% of its land area is forested. Landscapes are typically plains of either fluvial-lacustrine, glaciolacustrine, or till origin. Soils are therefore highly varied. Most of the agricultural soils are black to dark grey Chernozemic, grading to dark grey to grey Podzols on the forest fringes. A large Solonetzic zone is found near Tisdale. Due to the complex nature of the region's surficial geomorphology, soil texture is highly variable in many places, and locally, is often a combination of several types. Generally, soils are loamy in most places, but more sandy along the Saskatchewan River and clayey near Melfort-Tisdale. Although a number of typically 'high risk' soil types are present, the wind erosion risk ratings ascribed to most of the region are 'low' to 'negligible'.

6.6.2 Land-use and agriculture

The Nipawin region has the lowest percentage of cultivated land among the five cases (Table 6.6.1). Slightly more than one half of the total is cropped, with grazing and pasture accounting for less than 7%. Much of the remainder is forested (Figure 6.6.2 and Table 6.6.2).

Table 6.6.1: Nipawin land-use.

Land-Use Type	**Area (km^2)**	**% of Total**
Cropland	8,246	55.2
Woodland, Non-Productive	2,798	18.7
Woodland, Productive	2,414	16.2
Rough Grazing	983	6.6
Water	225	1.5
Wetland	130	0.9
Recreation Areas	71	0.5
Improved Pasture	27	0.2
Built-up Areas	27	0.2
Intensive Cultivation	3	0.0
Barren	2	0.0
Total	**14,926**	**100.0**

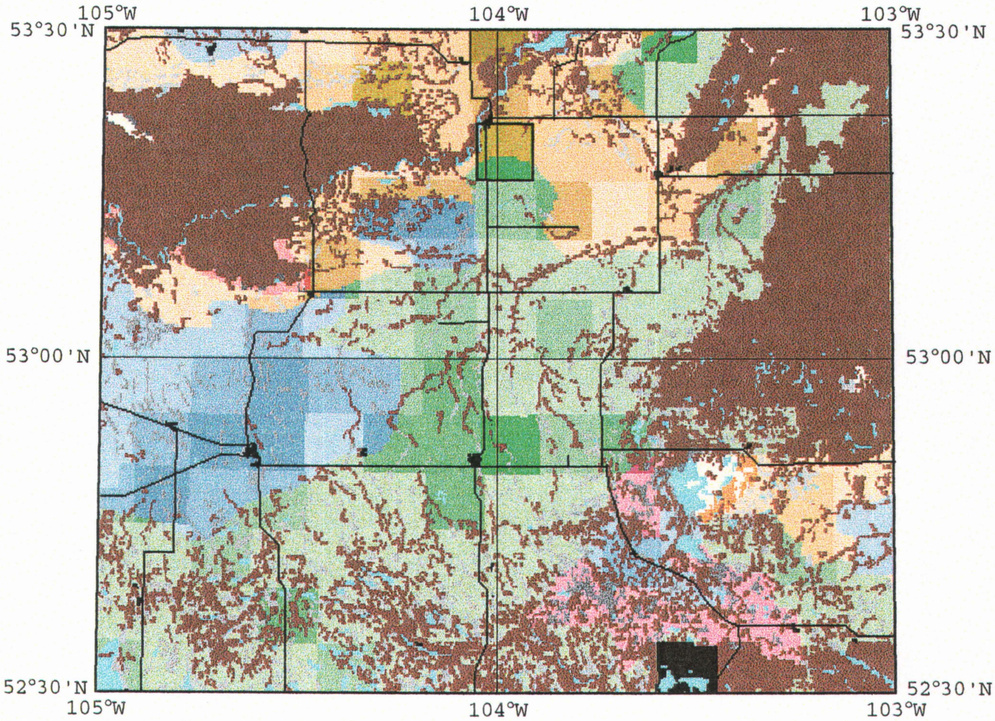


Figure 6.6.2: Nipawin land-use/wind erosion risk/ shelterbelt density overlay. Refer to Table 6.6.2 (following page) for an explanation of the zones.

Table 6.6.2: Nipawin landuse, wind erosion risk and shelterbelt distribution zones. (refer to Figure 6.6.2)

Map zone	**Area (km^2)**	**% total area**	**Zone description (Land-use, Wind Erosion Risk, Shelterbelt Density)***
	0	0.0	Cropland, Severe Risk, High Density
	3	0.0	Cropland, Severe Risk, Medium Density
	35	0.2	Cropland, Severe Risk, Negligible Density
	5	0.0	Cropland, High Risk, Medium Density
	5	0.0	Cropland, High Risk, Low Density
	259	1.7	Cropland, High Risk, Negligible Density
	432	2.9	Cropland, Moderate Risk, Medium Density
	590	4.0	Cropland, Moderate Risk, Low Density
	721	4.8	Cropland, Moderate Risk, Negligible Density
	169	1.1	Cropland, Low Risk, High Density
	474	3.2	Cropland, Low Risk, Medium Density
	731	4.9	Cropland, Low Risk, Low Density
	2837	19.0	Cropland, Low Risk, Negligible Density
	41	0.3	Cropland, Negligible Risk, Very High Density
	105	0.7	Cropland, Negligible Risk, High Density
	329	2.2	Cropland, Negligible Risk, Medium Density
	707	4.7	Cropland, Negligible Risk, Low Density
	744	5.0	Cropland, Negligible Risk, Negligible Density
	2	0.0	Cropland, Unrated Risk, Low Density
	30	0.0	Cropland, Unrated Risk, Negligible Density
	16	0.1	Rough Grazing/Impr.Pasture/Int.Cult, Severe Risk
	112	0.8	Rough Grazing/Impr.Pasture/Int.Cult, High Risk
	194	1.3	Rough Grazing/Impr.Pasture/Int.Cult, Moderate Risk
	508	3.4	Rough Grazing/Impr.Pasture/Int.Cult, Low Risk
	120	0.8	Rough Grazing/Impr.Pasture/Int.Cult, Negligible Risk
	58	0.4	Rough Grazing/Impr.Pasture/Int.Cult, Unrated Risk
	367	2.5	Water/Wetland
	5200	34.9	Woodland
	101	0.7	Built-up/Recreation/Mines and other Non-ag. Areas
			Unclassified

***NOTE:** Refer to Table 6.2.2.

Zonally, land-use largely corresponds to local topography and soils. Large blocks of continuous woodland remain on the region's eastern side, where both boreal forest and fen are more prevalent, but also in the marginal sandy areas near the Saskatchewan River. The majority of cropland is in the central portion where agriculturally favourable soils have developed in association with former grasslands. Rangeland is restricted to the Bjorkdale district in the south-east.

Befitting the most fertile part of Saskatchewan, the Nipawin region features the highest crop returns. Average wheat yields exceed 66 bushels/ha and year-to-year yields for all crops are more consistent than in other places. Since the mid-1980s, the reliance on wheat as a primary crop has dwindled. Over the past decade, wheat, barley, and canola have been planted equally. Almost one-fifth of the seeded land in 1996 was growing miscellaneous grains and forage crops. Although conservation farming practices have not been adopted on the scale seen in other locations, summerfallow has been nearly eliminated. The limit of practical farmland expansion may have been reached and the seeding of previously-fallowed land is one remaining way to increase production.

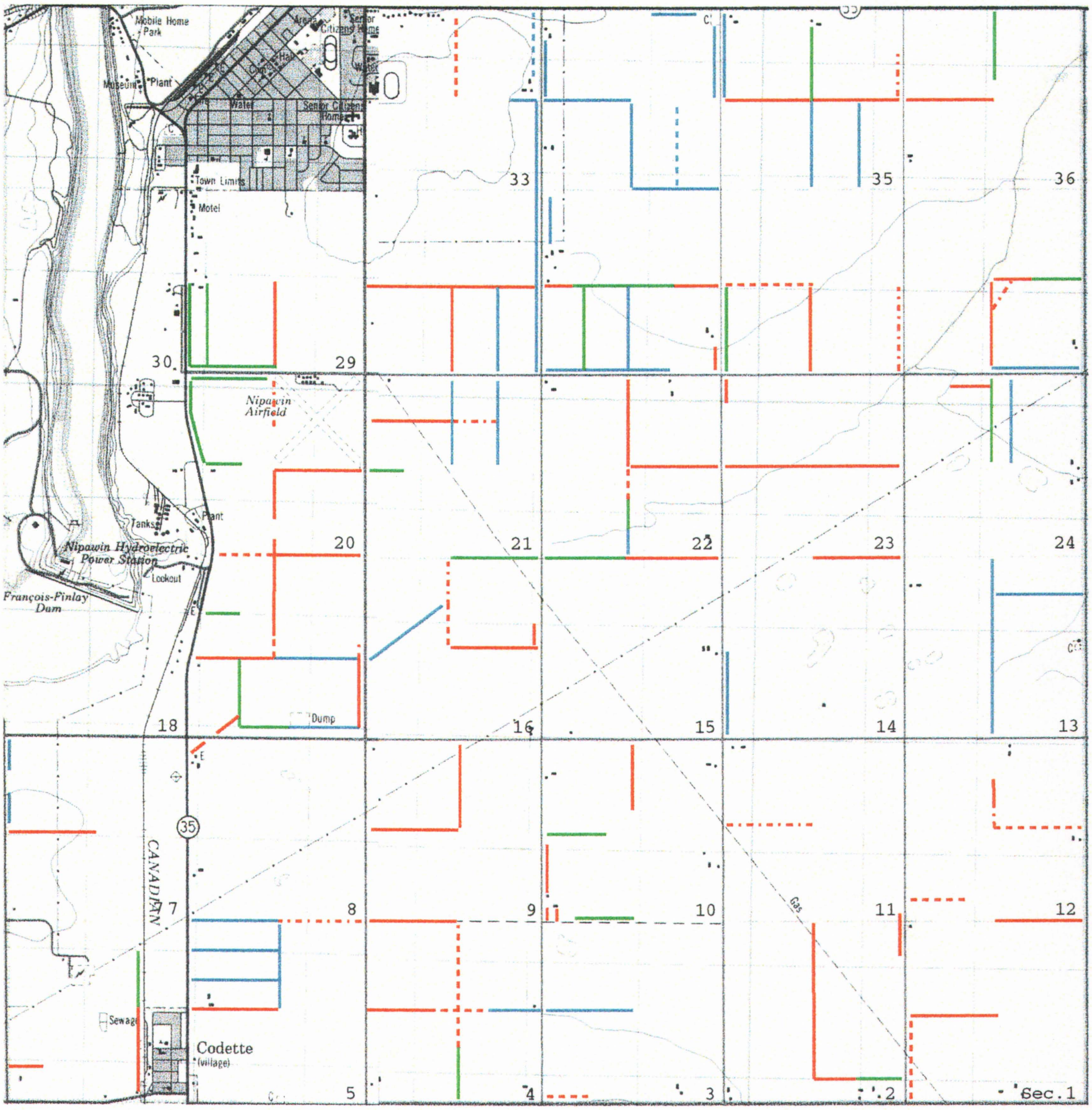
6.6.3 Historical shelterbelt change

The Nipawin case study township is located immediately south-east of the town for which it is named (Twp.50, Rge.14, W.2). It is situated in a zone of lush, nearly level farmland at low to negligible risk of wind erosion. The township receives nearly 450 mm of precipitation each year and readily supports agriculture.

Fifty-four miles of shelterbelt are visible on aerial photographs dating 1964 and 1980, and on the ground in 1999. Much of this mileage was in place before 1964 (Figure 6.6.3). Of the shelter of this vintage, seven miles have been removed or have deteriorated. An additional one mile of trees dating after 1980 has also disappeared. Various willow varieties are favoured for the Nipawin area (Figure 6.6.4) and shelterbelts of all types are notably healthy and luxuriant.

6.6.4 Interpretation

From 1949 to 1998, shelterbelt establishment in the Nipawin region has been limited. Except for a few isolated instances, (post-1960s plantings in the Nipawin and White Fox local areas), the PFRA record shows few trees distributed to region farms. Shelterbelts are not agriculturally necessary in much of the district for a



Planted: | Removed/Deteriorated by:

before 1964 — 1999 — 1980

1964-80

1980-99

1) Solid lines represent shelterbelts recognizable in the summer of 1999.
2) Broken lines represents shelter removed or deteriorated before 1999.

Figure 6.6.3: Shelterbelt placement for Twp.50, Rge.14, W.2. (Nipawin area), 1964-99.

Figure 6.6.4: Fully mature willow shelterbelt near Nipawin (observed August, 1999).

number of reasons. Climate conditions are moderate and adequate moisture is readily available to crops. Droughts are less severe here than in south-central Saskatchewan. Despite the occurrence of erosion-susceptible soil textures in several places, the relatively greater moisture amounts and typically lower wind speeds mean that approximately 40% of cropland receives either a 'low' or 'negligible' wind erosion risk classification. Additionally, soil fertility in parts of the Nipawin region is the highest in Saskatchewan and the resulting large crop returns probably further discourage area producers from planting artificial shelter. Finally, substantial natural tree growth provides significant protection to fields within the forest transition zone.

This final determinant is demonstrated by the shelterbelt mapping conducted in the Nipawin sample township. Here, there is a significant disparity between the mapped shelterbelt mileage and the density mileage calculated from the PFRA tree order history. Historical distribution records (Table 6.6.3) show only five miles worth of trees ordered in the 1950s, followed by an additional thirteen miles in the 1970s. Requests for willow seedlings comprised more than 70% of the trees (by mileage) shipped by the PFRA. In contrast, the 1999 field survey charted a substantial number of shelterbelts composed of rather disorganized mature poplar. It is suspected that these 'shelterbelts' were not deliberately planted but are the product of self-spreading poplar growing along fencelines and field edges (Figure 6.6.5). Some of these were evidently allowed to grow and provide shelter while others have been removed.

Because regional agricultural conditions (climatic, edaphic and economic) are highly favourable, and natural shelter is abundant, it suspected that indeterminate factors have played a large role in Nipawin's local

Table 6.6.3: Field-type shelterbelt tree distribution record for Twp.50, Rge.14, W.2, 1949-98.

Sec.	Year	Type	App.Dist (mi)	Number	Species	Plt.Dist. (ft)	Calc.Dist. (mi)
	98	Field		150	Silverleaf Willc	6	0.17
	88	Field		700	Acute Willow	6	0.80
	86	Probable		500	Willow	6	0.57
	83	Field		300	Acute Willow	6	0.34
	83	Probable		200	Laurel	6	0.23
	83	Probable		200	Silverleaf Willc	6	0.23
	81	Road		300	Acute Willow	6	0.34
27	78	Combined	1.5	300	Laurel	6	0.34
				400	Siberian Larch	6	0.45
				10	Col. Spruce	10	0.02
				20	Scots Pine	10	0.04
29	78	Field	0.5	30	Chokecherry	3	0.02
				250	Siberian Larch	6	0.28
				250	Laurel	6	0.28
				350	Buffaloberry	3	0.20
				300	Col. Spruce	10	0.57
				200	White Spruce	10	0.38
17	76	Field	0.5	980	Acute Willow	6	1.11
17	75	Combined	1.5	2,000	Laurel	6	2.27
5	74	Field	2	25	Amur Maple	6	0.03
				1,000	Acute Willow	6	1.14
				25	Villosa Lilac	3	0.01
				30	Col. Spruce	6	0.03
				30	Scots Pine	6	0.03
5	73	Field	1.5	3,780	Acute Willow	6	4.30
				200	Col. Spruce	6	0.23
				40	Scots Pine	6	0.05
24	70	Field	1	2,500	Caragana	1	0.47
				700	Willow	4	0.53
2	69	Rur. Hldg.	0.25	350	Willow	4	0.27
15	67	Field	0.5	675	Acute Willow	4	0.51
2	64	Probable		2,000	Caragana	1	0.38
24	54	Field		2,600	Acute Willow	4	1.97
2	51	Probable		1,325	Man. Maple	6	1.51
2	51	Probable		1,325	American Elm	6	1.51
			Totals:	**24,045**			**21.60**

shelterbelt history. In the sample township, it is possible that shelterbelts have been planted simply because they thrive there and their existence augments the aesthetic character of the district. An observed example is the 500 spruce planted in Sections 20 and 29, mostly alongside Highway 35, which provide a very picturesque approach into the town of Nipawin. Similarly, the large number of mature willow shelterbelts also provide scenic enhancement. As with the other cases, a survey of landholders is required in order to fully explain the shelterbelt history of the area.

Figure 6.6.5: One of many poplar 'shelterbelts' growing near Nipawin in August, 1999.

Chapter 7
Interpretation
-Shelterbelt Determinants versus Distribution and Use-

7.1 Introduction

The three previous chapters have presented the following: a description of the study area, historical contexts of shelterbelt use, the principles of field shelterbelts, an overview of tree distribution patterns since 1949, and the characteristics of five case studies. Contemplation of this information leads to an obvious question: "Why have field shelterbelts been placed where they have been?". To answer this, the determinants and contexts must be revisited, and their relevance to the shelterbelt history of Saskatchewan analyzed.

7.2 Physical—Environmental Setting

Undoubtedly, the physiographic parameters of any specific location highly influence a landowner's decision to plant field shelterbelts. The physiographic nature of a place in terms of climate, soils and ecology decides, among other things, the potential for soil loss and moisture deficit, problems ameliorated by windbreaks.

Regional climate varies across Saskatchewan. Whereas the dry belt of the province's south-centre/south-west can be marginal or completely unsuited to mono-crop agriculture, the north-east provides an excellent agricultural environment. The greatest fifty-year concentration of field shelterbelts is located in a band extending from Saskatoon southwards through Outlook and Swift Current. The warm, dry, windy character of this area, especially between Lake Diefenbaker and Swift Current, has been a primary factor in past eolian erosion and agricultural drought events which were likely the impetus of several shelter projects.

The nature of local soils, in terms of their susceptibility to erosion and pervasive moisture deficit, can also be a prime incentive for establishing shelterbelts. For example, the Chernozemic zone of south-west Saskatchewan, with its reduced organic content and lower moisture reserves, is typified by relatively high shelterbelt densities. However, in the case of soils, texture is the more important factor. The highly erodible Regosolic soils lying along the South Saskatchewan River north and south of Saskatoon show proportionately higher concentrations of shelterbelts, as do several other sandy areas across the province. Nevertheless, caution should be exercised when drawing conclusions based solely on soil texture and wind erosion risk information. As was observed in the Midale and Cadillac case studies, many highly vulnerable areas are either pasture or rangeland and, as they are permanently vegetated, do not require artificial protection.

Natural permanent vegetation has had more influence on shelterbelt spatial density than may, at first, be recognized. Whereas little difference in shelterbelt distribution is observed between the two grassland ecoregions, there has been a conspicuous paucity of shelterbelt trees shipped to locations in the aspen parkland and boreal transition zones. This is particularly noticeable for much of eastern Saskatchewan. It can be assumed that, for places within these eco-zones, naturally-growing bluffs provide a reasonable degree of protection, thereby rendering artificial windbreaks superfluous. The propensity for tree growth can be so pronounced that, in some areas, *natural* field shelterbelts are found. This phenomenon was observed in the Nipawin case study, and applies to several places along the northern agricultural fringe. In Nipawin, such windbreaks have been allowed to flourish, but undoubtedly, in many other places, they are seen as a nuisance to be removed.

7.3 Agricultural Contexts

The modeling of an agricultural hazard system in Chapter 4 demonstrates that the presence of an adverse physical condition is usually not the sole incentive for artificial protection measures until anthropogenic activities have exaggerated its effect on human-use systems. For example, except on the most-exposed dunes, soils that are prone to erosion will not be damaged until tillage exposes them.

Following the drought and erosion disasters of 1917-20 and the 1930s, much marginal cultivated land reverted to permanently vegetated rangeland. On these lands, shelterbelts are of limited use and their benefits may not be sufficient to justify their cost. The effect of land-use on shelterbelt tree distribution was proven with the land-use/shelterbelt density comparisons of Chapter 6. It also explains the scarcity of shelterbelts in some of the study area's most vulnerable locations, for example, those near Fox Valley and Eston.

There is also evidence of a relationship between agricultural practice and shelterbelt distribution. Often, soil erosion and soil moisture problems are inextricably linked to an agricultural system choice. For the prairies, it is estimated that naturally vegetated (grass-covered) soils lose less than 0.01 mm of topsoil per year. Cultivated crops, however, can lose up to 3 mm, and tilled summerfallow relinquishes an additional 5-6 times *this* amount (Lerohl and van Kooten, 1995).

Tilled summerfallow provides a good illustration of a human activity exacerbating natural risk conditions. This long-used moisture preservation and weed-arresting method, initiated early in Saskatchewan's agricultural history by farming experts such as Motherwell, is directly responsible for a large share of historical soil loss. Field shelter has traditionally been prescribed as a useful counter-measure to the harmful effects of what was viewed as an 'absolutely necessary' practice. This tenet evidently still holds true in south-west Saskatchewan where Swift Current—Cadillac producers strenuously maintain the summerfallowing tradition while, at the same time, continue to order more shelterbelt trees.

The relationship between agricultural practice and shelterbelts may be evolving though. As more producers adopt conservation farming methods such as minimum-tillage, they may have less need for field protection. It is probable that this change in practice is largely responsible for the overall downward trend in shelterbelt orders received following the 50-year peak observed in 1991. 1998, the last year for which data was analyzed for this thesis, saw the lowest number of trees distributed from Indian Head since 1960.

Nevertheless, summerfallowing continues to be practiced across the province, even though it has been found to be of dubious benefit for much of Saskatchewan. Bootsma *et al.* (1992a) have ascertained that for 50% of all years, the soil moisture gain from fallowing is less than 20 mm; even in the dry south-west where the technique is most beneficial. For nine out of ten years, approximately one-half of agricultural Saskatchewan receives no gain. Yet, in spite of, (or perhaps because of), the 1980s droughts, the 1996 agricultural census listed 22% of Saskatchewan cropland as still being tilled summerfallow.

7.4 Economics

'Economics' (or more precisely, capital outlay) has been cited as the most important factor in the adoption of soil conservation practices (Wettlaufer and Brand, 1999). That is, a realized return must be evident in order for the adoption of shelterbelts or any other conservation method to extend beyond the "environmentally committed".

Traditionally, a balance has had to be achieved between limiting soil loss and retaining sufficient moisture for crops. The economic implications of this are not always easily ascertained. In terms of the economic cost of soil loss, some research has arrived at figures nearing $1 billion annually for the prairies as a whole (cited in Lerohl and van Kooten, 1995). The latter researchers have disputed such numbers, arguing that loss due to erosion must be balanced against the cost of alternate cropping methods (land reversion, chemical-fallowing, continuos cropping, reduced tillage and so on). In dryland farming, it is argued, each of these alternatives typically results in lower net economic returns. Zero-tillage is considered the exception, showing eventual net gain after related costs (fuel and herbicide) are factored in.

7.5 Policy

Undoubtedly, public programs have been a major driving force behind shelterbelts. The fact that the PFRA has, since 1935, continued to provide shelterbelt trees free of charge to producers is surely the reason most Saskatchewan shelterbelts exist.

The temporal changes in distribution observed in this study are, in several cases, a product of more specific initiatives. An example is the 'Save Our Soils' (SOS) component of the Canada-Saskatchewan Agreement on Soil Conservation. This program was largely responsible for the phenomenal number of shelterbelt plantings witnessed in the early 1990s. SOS grew out of the 1984 Economic and Regional Development Agreement (ERDA) and National Soil Conservation Program (NSCP), and was jointly administered by the PFRA and the SAF – Agriculture Development Fund. The program's objectives were as follows: to promote soil management, educate producers in soil conservation methods, reduce off-farm environmental impacts of soil degradation, and promote cooperation amongst various groups concerned with rural environments (Agriculture Canada, 1989). Field shelterbelts were an important component of the program and local 'conservation clubs' were highly involved in arranging funding from both the ERDA and Agriculture, Development and

Diversification (ADD) programs for a variety of initiatives (Table 7.5.1). One example is the financing of tree planting equipment which was subsequently made available to interested producers (Wettlaufer and Brand, 1999). At the local level, administration and planning was the responsibility of the provincial ADD boards. The SOS part of the NSCP ended in 1993, but soil conservation initiatives continue and are considered a priority under the National Green Plan for 'sustainable agriculture' (Wettlaufer and Brand, 1999).

Table 7.5.1: Funding for Saskatchewan local group soil conservation programs 1984-94 (in $CDN). (after Wettlaufer and Brand, 1999)

Year	Federal	Provincial	Total for Year
1984/85	0		0
1985/86	330,000		330,000
1986/87	966,000		966,000
1987/88	1,220,000		1,220,000
1988/89	1,100,000		1,100,000
1989/90*	214,000	607,800	821,800
1990/91	2,604,700	1,780,500	4,385,200
1991/92	2,456,400	910,400	3,366,800
1992/93	3,292,400	663,000	3,955,400
1993/94	300,000	974,000	1,274,000
Total	**12,483,500**	**4,935,700**	**17,419,200**

* **Note**: Funding administration switched from ERDA to ADD in 1989/90.

7.6 Human Implications

The human aspects of field shelterbelt placement are varied and are not easily discerned. As they are not simple, they also require substantial research and explanation. It is not within the scope of this thesis to investigate all of the complex human rationales involved in shelterbelt placement, but to attempt to explain those most easily defined.

One human determinant that has been considered is 'cultural' predisposition to use. It is very difficult to quantify and assess whether individual cultural groups in Saskatchewan were influenced by the "international gospel of trees" that Rees (1988) ascribed to European and American immigrants. However, when comparing the settlement and distribution maps (Figures 3.1.8 and 5.4.1), it does seem that relationships exist in some locations. The most obvious example is the preponderance of shelterbelts in the Mennonite-settled areas south of Swift Current and north of Saskatoon. Conversely, the Austro-Hungarian/Ukrainian inhabited lands near Yorkton and Melville show very little adoption of shelterbelts.

Extreme care must be taken when formulating suppositions based on potential cultural influences on shelterbelt use as other determinants must also be addressed. However, in instances where there is little difference in physiographic and economic character between two places, Yorkton and Rosthern, for example, one must question whether cultural factors have indeed entered the process. Certainly, Britain and southern Russia (the pre-emigratory homeland of most Saskatchewan Mennonites), two places of origin for much of Saskatchewan's agricultural population, have had a long tradition of using sheltering trees (Caborn, 1965; Gray, 1967). The consideration of possible cultural correlation and the other human factors poses interesting questions that will hopefully be addressed in a future study.

Several other 'human' factors deserve recognition. Perception of, and attitude towards, field shelterbelts is likely the most important of these. There is some evidence that much of the early 1990s shelterbelt planting was frequently a function of a local ADD board representative's personal level of enthusiasm for shelterbelts. It is also entirely possible that shelterbelts have *not* been placed where they might be useful simply because an individual held a negative perception of them. As with most human determinants, the only method of investigation that can provide insight to this phenomenon is to survey individual landowners.

Sutton (1983) conducted such a survey in the Lyleton area of south-west Manitoba. Lyleton was one of the original PFRA experimental sites (analogous to Conquest and Aneroid), and, therefore, has a long history of field shelterbelt use. Sutton discovered producers had several reasons for not planting field shelterbelts. Among those offered were the following: "they (shelterbelts) were too time consuming", "other soil conservation practices were being used", and "adjacent crops did not grow well". 60% of landowners without shelterbelts proclaimed that they would not plant any in the future.

Noting that 61% of Lyleton shelterbelt users had removed shelterbelts in the past, Sutton also made enquiry into the reasons existing shelters were being eliminated. Interference with equipment maneuvering was cited by three-quarters of the respondents as the primary reason for removal; but in almost all cases, only the shelterbelt *ends* were taken. Other reasons were also cited; principally, that shelterbelts made the fields too small. Sutton concluded, however, that "landowners are not totally clearing their land of shelterbelts but merely opening up fields". Of those with shelterbelts, four-fifths said they would not remove any in future. Interestingly, of *all* Lyleton respondents, 91% asserted that shelterbelts were necessary for soil conservation. Lyleton producer attitudes are summarized in Tables 7.6.1, 7.6.2, and 7.6.3.

An anecdotal footnote perhaps best illustrates how far-ranging the set of perceptions and attitudes held by individuals can be. During the course of an informal conversation, a long-time farmer from the Qu'Appelle district remarked that while one "had to have" shelterbelts (a view possibly arrived at because he had been influenced by the nearby PFRA Indian Head Shelterbelt Centre), it was

Table 7.6.1: Perceived benefits of field shelterbelts. (Frequency of responses from all respondents in agreement of selected benefits of field shelterbelts). (after Sutton, 1983)

Benefit	**Response (%)**
Reduces blowing out of newly seeded crops	97
Reduces soil erosion	91
Provides habitat for wildlife	91
Improves appearance of countryside	91
Reduces the number of windblown swaths	84
Reduces abrasion damage to seedlings	83
Reduces fill-in of drainage ditches from drifting soil	56
Improves growing condition for crops	41
Increases crop yields	37
Eliminates snow blockage problems in drainage systems	11
Facilitates chemicals and irrigation water distribution	11

Table 7.6.2: Perceived disadvantages of field shelterbelts. (Frequency of responses from all respondents in agreement of selected disadvantages of field shelterbelts). (after Sutton, 1983)

Disadvantage	**Response (%)**
Dead branches blowing onto fields	73
Moisture loss to trees adjacent to crops	66
Division of large fields into smaller ones	60
Interference with equipment maneuvering	56
Trees damaged or killed by crop spraying	53
Over-accumulation of snow delaying spring work	39
Weeds in shelterbelts spreading to fields	33
Land occupied by shelterbelts is taxed	30
Shelterbelt use of cropland	28
Interference with herbicide application	27
Trees damaged by cattle	27
Interference with irrigation systems	25
Land occupied by shelterbelts cannot be included in quota	23
Water erosion from excess snow	20
Loss of effectiveness upon aging	20
Trees damaged or killed by insects	20
Trees damaged or killed by disease	20
Shelterbelts expensive to plant and maintain	12
Interference with cattle grazing	12
Time required to plant and maintain	9
Interference with stubble burning	9
Trees damaged or killed by wildlife	5
Shelterbelts attract undesirable wildlife	5

Table 7.6.3: Perception of field shelterbelt cost. Frequency of responses from landowners with, and without shelterbelts, that the benefits of field shelterbelts outweigh the costs. (after Sutton, 1983)

Rank	Response (%) (with Shelterbelts)	Response (%) (without Shelterbelts)
strongly agree	55	10
agree	37	30
neutral	7	50
disagree	0	10
strongly disagree	0	0

"good for the fields to have a good blow", meaning soil migration was beneficial. His reasoning was simply that his 1930s-era vegetable and flower gardens were the most prosperous he'd ever had, (one can surmise that his gardens were the beneficiaries of topsoil lost from nearby unsheltered fields).

This example is merely a curiosity in the context of this study. However, it serves to demonstrate that in many cases, the rationale behind field shelterbelt planting cannot simply be defined as a set of solutions based on formulae computing natural and anthropogenic variables. Rather, it is likely to be an answer arrived at by each *individual* land-owner, whereby he or she has applied his or her own personal experience, attitudes, beliefs and reasoning to the local conditions, and only then makes a decision as to whether or not trees will be planted.

Chapter 8
Conclusions

The objectives of this research were fourfold: determine where field shelterbelts are concentrated in Saskatchewan; outline their history of use; characterize the shelterbelt types, designs, and species employed; and finally, attempt to answer why they were planted where they were. These aims have been answered and a number of summations can be made.

Firstly, field shelterbelts do show notable distribution patterns. For example, the western part of the province, particularly in a band stretching from Saskatoon to Swift Current, has received a greater proportion of shelterbelt trees than has eastern Saskatchewan. Furthermore, these spatial patterns have also been subject to historical variation. An illustration of this is observed where planting activity for a particular location has been high for a short period, but then declined. This was the case in the Wilkie-Unity area during the 1970s, but conversely, other places have shown continuous sheltering efforts throughout the study period.

One objective of the study intended to address the fear of widespread shelterbelt deterioration and removal expressed by several researchers during the mid 1970s (Goldsmith, 1976; Neidig, 1976; Sorenson and Marotz, 1977; and Waldron and Hidahl, 1974). This investigation has revealed that shelter degeneration does not appear to have occurred on a significant scale. Indeed, distribution statistics up to the early 1990s showed the opposite to be true. Although new shelterbelt mileage has recently dwindled, the case studies show little evidence of meaningful removal of existing trees. It is assumed that predominantly favourable attitudes towards field shelter (Sutton, 1983) have prevailed in Saskatchewan. As evidence, one need look no further than Conquest, where, despite several decades when there was little requirement for additional shelter, a sizable number of trees are still sent. Area residents hold great pride in their shelterbelts and it is suspected that a majority of other Saskatchewan landowners with windbreaks feel likewise.

Several Saskatchewan shelterbelt character aspects have been discussed. Many planting types falling within a broad 'field' category have been investigated. Each is designed to mitigate hazardous meteorological or edaphic conditions, principally manifested as eolian erosion. This and many other rural problems have been addressed by shelterbelts of several designs. Closely allied to the intended purposes of shelterbelts are the wide variety of species used over the 50-year study period. Often the species choice has been imposed as much by the nature of the local habitat as by design. This is reflected by the 'universal' species such as caragana and green ash that grow across the province, while others, such as willow, are more geographically restricted in use.

Finally, factors influencing shelterbelt use (determinants) have been discussed. These are system inputs that have proven to be highly diverse in origin. They are grounded in underlying environmental conditions, human-use activities, or in interactions between the two. Historical and contextual elements have also had a demonstrable role. Several determinants are easily identified, for example, the calculable risk of wind erosion, but others may be more ambiguous. Examples of the latter are typically cultural influences, the role of aesthetics, and other such variables.

While there are many reasons to plant shelterbelts, and likely several not to, it is not unreasonable to suspect that measurable environmental and human-use determinants are not singular driving factors. That is, there are no hypothetical rules to the effect that "shelterbelts are to be planted when local wind speed reaches 20 km/h, 19 days out of 20", and so on. It is more credible that an individual *set* of determinants is applicable to each application case. These typically consist of a perceived need (to prevent the loss of recently seeded crops, for example), combined with measurable inputs such as high local wind speed, and other less quantifiable ones (e.g. a farm family's history of use, etc.).

The rather indistinct nature of some determinants of use does not take away from the many qualities of Saskatchewan field shelterbelts identified within this thesis, but merely illustrates a need for continuing research. In reference to the stated objectives of this study, upon consideration of *all* aspects of shelterbelt application, four conclusive summations can be made:

1) Saskatchewan field shelterbelts *do* show spatial distribution patterns which, (to varying degree), correspond to a number of quantifiable environmental determinants. This is evident in the dry, high wind erosion risk areas of the Lake Diefenbaker district, where the greatest concentration of field shelterbelt use is found.

2) Temporal fluctuations in tree distribution, independent of supply inconsistencies, are also apparent; seemingly coinciding with documented historical economic, human-use and climatic fluctuation. This was observed following the late-1980s droughts, when policy favouring field shelterbelts initiated a very high adoption rate of new shelter in the early 1990s.

3) Shelterbelt placement cannot usually be defined by a single determinant, as the interrelationship between the many physical, human, and historical-contextual factors is multivariate and complex. In all cases investigated, shelterbelt establishment was the result of climatic, edaphic, policy, agricultural-historical, and many other factors.

4) Several enigmatic human factors have evidently played a role in both spatial and temporal distribution patterns.

Obviously, the final point renders this study somewhat incomplete as not all questions have been answered. The solution, a survey of landowners who have made the decision to plant or not, awaits fulfillment.

A final query deserves consideration. This may be expressed as "What is the *future* place of field shelterbelts within Saskatchewan agriculture?". It is highly possible that the number of new shelterbelt plantings will continue to decline as alternative soil conservation techniques gain more widespread acceptance. This is certainly suspected in the example of 'minimum-tillage' (direct seeding). Once the heavy investment required by this system is made, producers may not be interested in additional long-term shelter projects, and might even perceive them as being redundant. Lerohl and van Kooten (1995) have stated that almost all conservation practices aside from zero (minimum) tillage are not economically sensible in the short-term. And quite possibly, with immediate financial feasibility concerns being expressed by many 'family' farmers, long-term advantages may not be seen as being any benefit to producers who are contemplating the surrender of their farms. Hopefully, a strictly short term focus does not characterize the majority of Saskatchewan's agricultural operations. However, it remains to be seen whether field shelterbelts will be re-embraced as producers evaluate all viable options for maintaining productivity, or if they will indeed be judged superfluous in increasingly technologically-driven 21st century agriculture.

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Appendix A
Preliminary Distribution Mapping

During the initial stages of this research, PFRA distribution data for the 1980s and 1990s were used to map both field *and* farm type shelterbelts at an RM scale. The effort served to establish a theoretical framework for the study's objectives and allowed refinement of the analytical process. As described in Chapters 2 and 4, the preliminary mapping led to decisions to increase the mapping unit scale, alter the measurement of shelterbelt density, and limit the types of shelterbelt that would be mapped. The differences between the primary and preliminary shelterbelt maps should be noted and are summarized in Table A.1.

Table A.1: Differences in mapping characteristics; primary and preliminary shelterbelt density maps.

	Primary Mapping (Chapter 5)	**Preliminary Mapping (Appendix A)**
Years mapped	1949-98	1984-98
Temporal scales	Long-term (50-year) Short-term (5-year)	Short-term (5-year)
Mapping resolution (spatial scale)	Township (36 mi^2)	RM (vary in areal extent, typically 9 twps.)
Measure of shelterbelt density	Calculated linear shelterbelt mileage per twp.	Number of trees per RM
Types of shelterbelt mapped	Field-type (includes field, road, etc.)	Field-type and farmyard

Figures A.1 and A.2 show the RM-scale mapping results for farm and field shelterbelt distributions respectively. Both use the same density scale, and each has been mapped for three, 5-year intervals; the dates of these correspond to the short-term maps of Chapter 5. The most notable dissimilarity between the farm and field maps is the relative spatial and temporal uniformity of the farm shelter distribution versus the more patterned apportioning observed for field-types. Several other differences are also apparent.

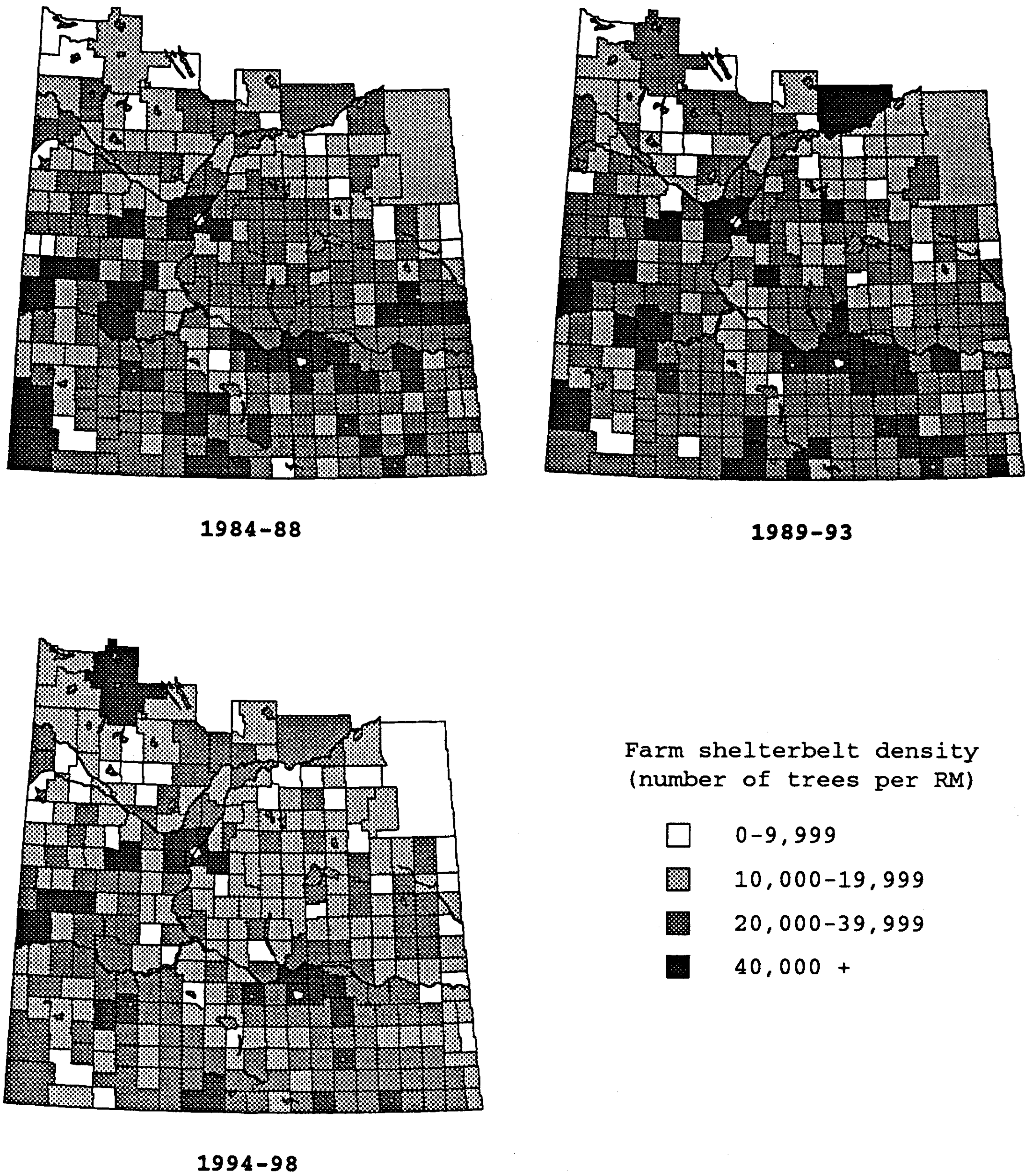

Figure A.1: Farm shelterbelt density, 1984-98.

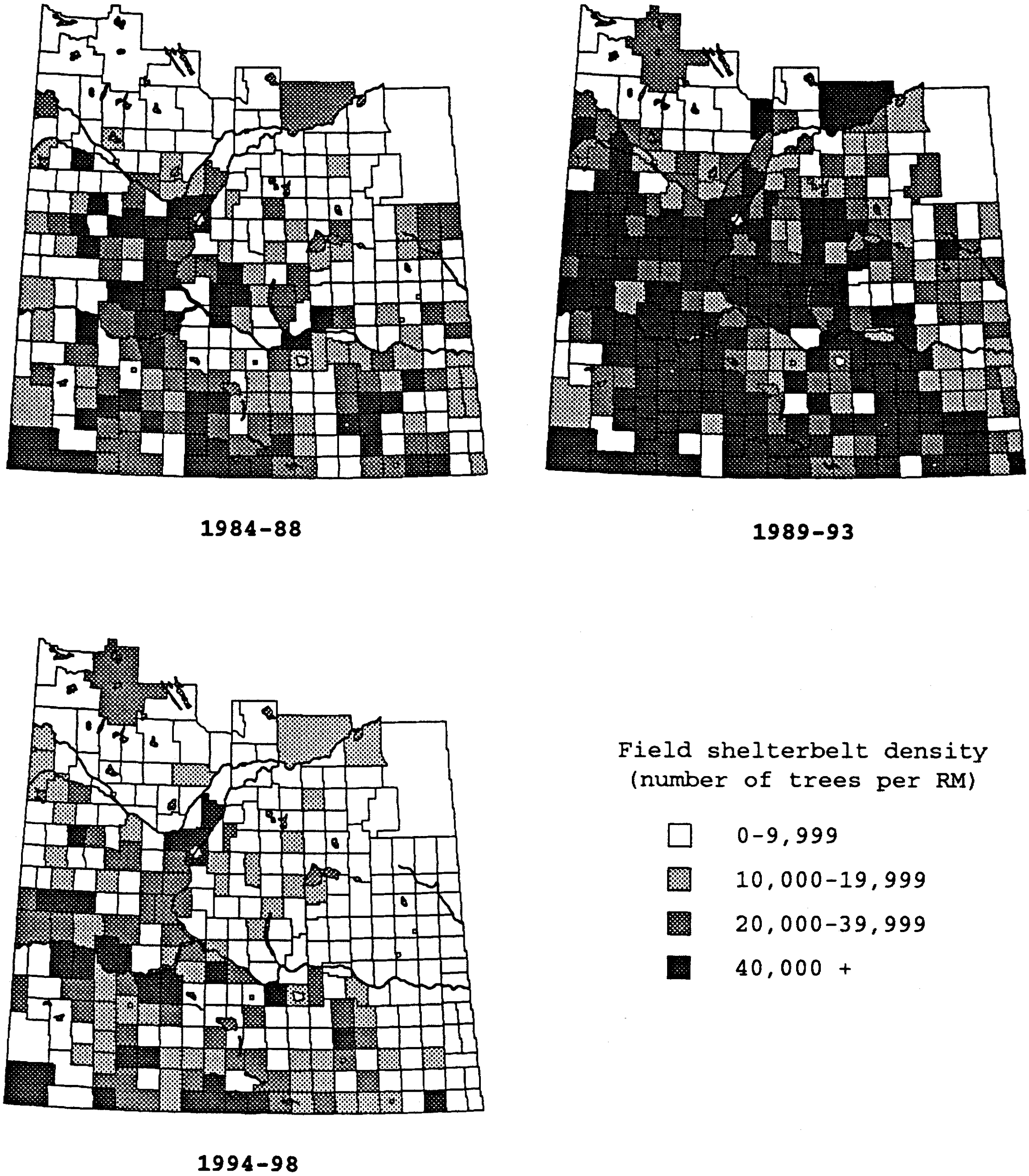

Figure A.2: Field shelterbelt density, 1984-98.

Appendix B
Shelterbelt Species

As discussed in Chapter 2, a measure of 'shelterbelt density' was calculated using the selected windbreak species' "standard planting distance" (the spacing between individual plants in a shelterbelt row). Table B.1 identifies these distances in both feet (the measure used for calculation), and metres. Table B.2 lists all identifiable species recorded as shipped for field-type applications along with their corresponding standard planting distances.

Table B.1: Typical field shelterbelt planting distances.

Spacing (ft)	Spacing (m)	Spacing (ft)	Spacing (m)
1	0.3	6	2.0
3	1.0	8	2.5
4	1.3	10	3.0

Table B.2: Field shelterbelt species (by common name) with standard planting distances used in calculations.*

Species	Spacing (ft)	Species	Spacing (ft)
38P38 poplar	6	Manchurian crab	3
44-52 poplar	6	Manitou poplar	6
Acute willow	6[1]	North West poplar	6
American elm	6	Preston lilac	3
Amur maple	6	Red elder	3
Green ash	6	Russian olive	6
Assiniboine poplar	6	Russian poplar	6
Basford willow	6[1]	Sandthorn	3
Brooks poplar	6	Saskatoon	3
Buffaloberry	3	Scots pine	10[2]
Bur oak	8	Seabuckthorn	3
Can-Am poplar	6	Siberian crab	3
Caragana	1	Siberian elm	6[3]
Chermisina willow	6	Siberian larch	6
Chokecherry	3	Silverleaf willow	6
Colorado spruce	10[2]	SK poplar	6
Dogwood	3	Snowberry	3
Dunlop poplar	6	Ussurian pear	4
Elder	3	Villosa lilac	3
Hawthorne	3	Walker poplar	6
Hedgerose	3	White spruce	10[2]
Honeysuckle	3	unspecified conifer	6
Japanese elm	6	unspecified lilac	3
Juniper	3	unspecified poplar	6
Larch	6	unspecified shrubs	3
Laurel	6[1]	unspecified willow	6[1]
Manitoba maple	6		

Notes:

* Recently, recommended spacing for many deciduous trees including green ash, Manitoba maple, poplars, siberian elm, and willows, has been increased by 2 feet to 8 (2.5m). Coniferous tree spacing has also been widened to a standard 12 ft (3.5m).

[1] shipments prior to 1976 are calculated at a 4 ft spacing
[2] shipments prior to 1975 are calculated at a 6 ft spacing
[3] shipments prior to 1972 are calculated at a 3 ft spacing

Appendix C
Climate Statistics

A number of climate statistics have been included within this research. These represent calculations based on monthly mean values obtained from Environment Canada. This appendix graphically presents selected data for the principal meteorological parameters described in Chapters 3 and 6. Five data sets derived from seven meteorological stations are denoted. The stations, parameters, and record dates used in this research, correspond to the case study locations of Chapter 6 and are listed in Table C.1. It should be noted that although temperature and precipitation information was recorded for all years indicated, missing data has prevented accurate calculation of annual totals and means in some cases. Calculated statistics for years with incomplete records have not been graphed.

Table C.1: Climate data stations and years of data records.

Station Name	Environment Canada ID	Temp. Record Span	Precip. Record Span	Wind Record Span
Weyburn Airport	4018760	1953-92	1953-92	1963-92
Swift Current Airport	4028040	1949-92	1949-92	1953-93
Davidson	4012120	1949-89	1949-89	–
Outlook PFRA	4055736	–	–	1963-92
North Battleford Airport	4045600	1949-92	1949-92	1953-93
Nipawin Airport	4075518	1974-92	1974-92	1974-93
Nipawin2	4075520	1949-73	1949-73	–

Selected temperature changes over the study period may be consulted in figures C.1.1 through C.1.6. Figures C.2.1 through C.2.7 similarly outline monthly mean rainfall and snowfall. Historical temperature and precipitation figures have been presented using both a long-term and five-year temporal scale, corresponding to that used in the shelterbelt distribution mapping of Chapter 5. Wind information is of particular interest in any study of shelterbelts. Mean hourly wind speeds and prevailing wind direction, by month and year, are portrayed in figures C.3.1 through C.3.3. All wind statistics are long-term normals. This is considered appropriate as regional-scale wind characteristics are not believed to change appreciably over 30-40 years.

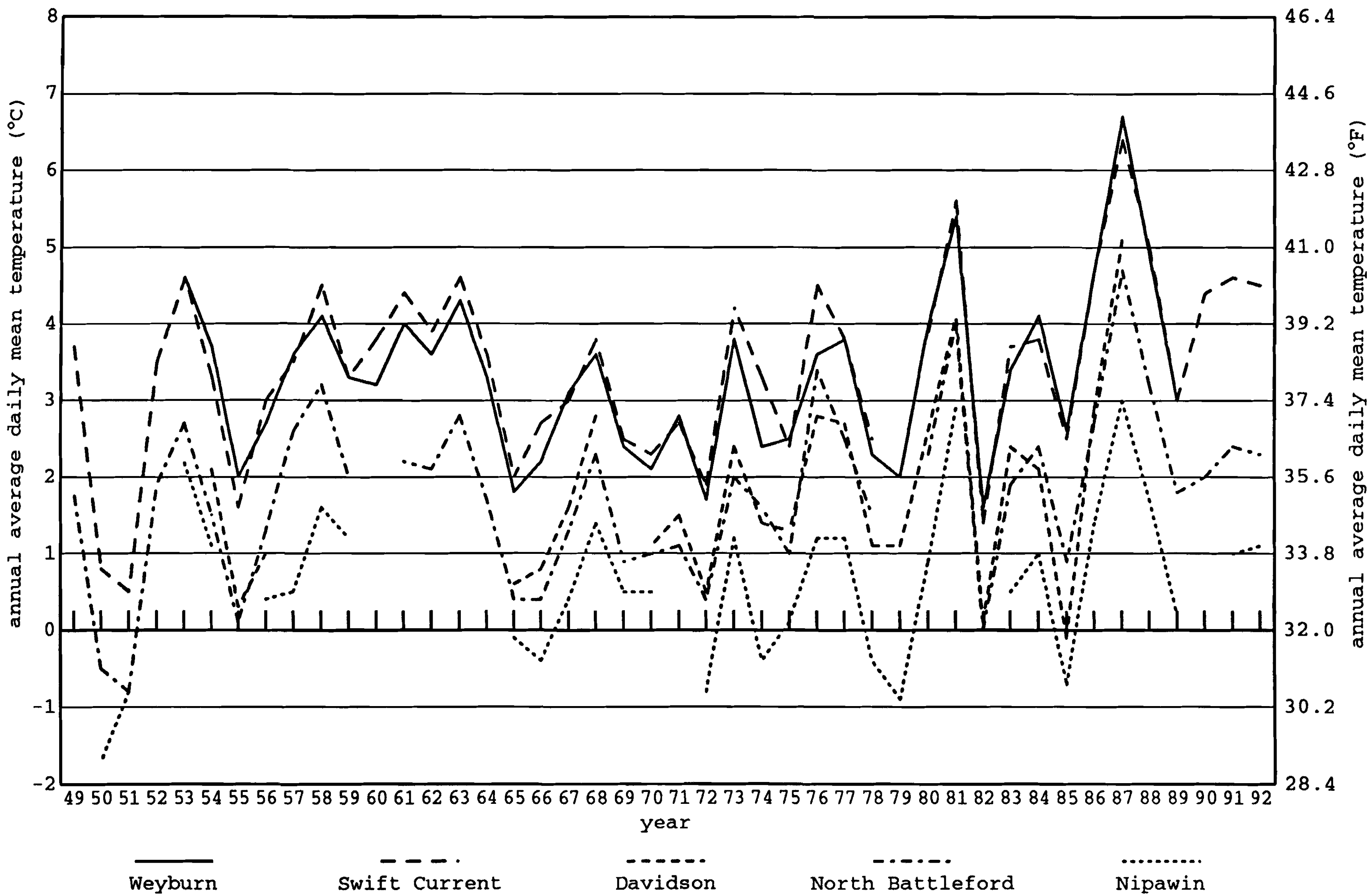

Figure C.1.1: Annual average daily mean temperatures for selected locations, 1949-92.

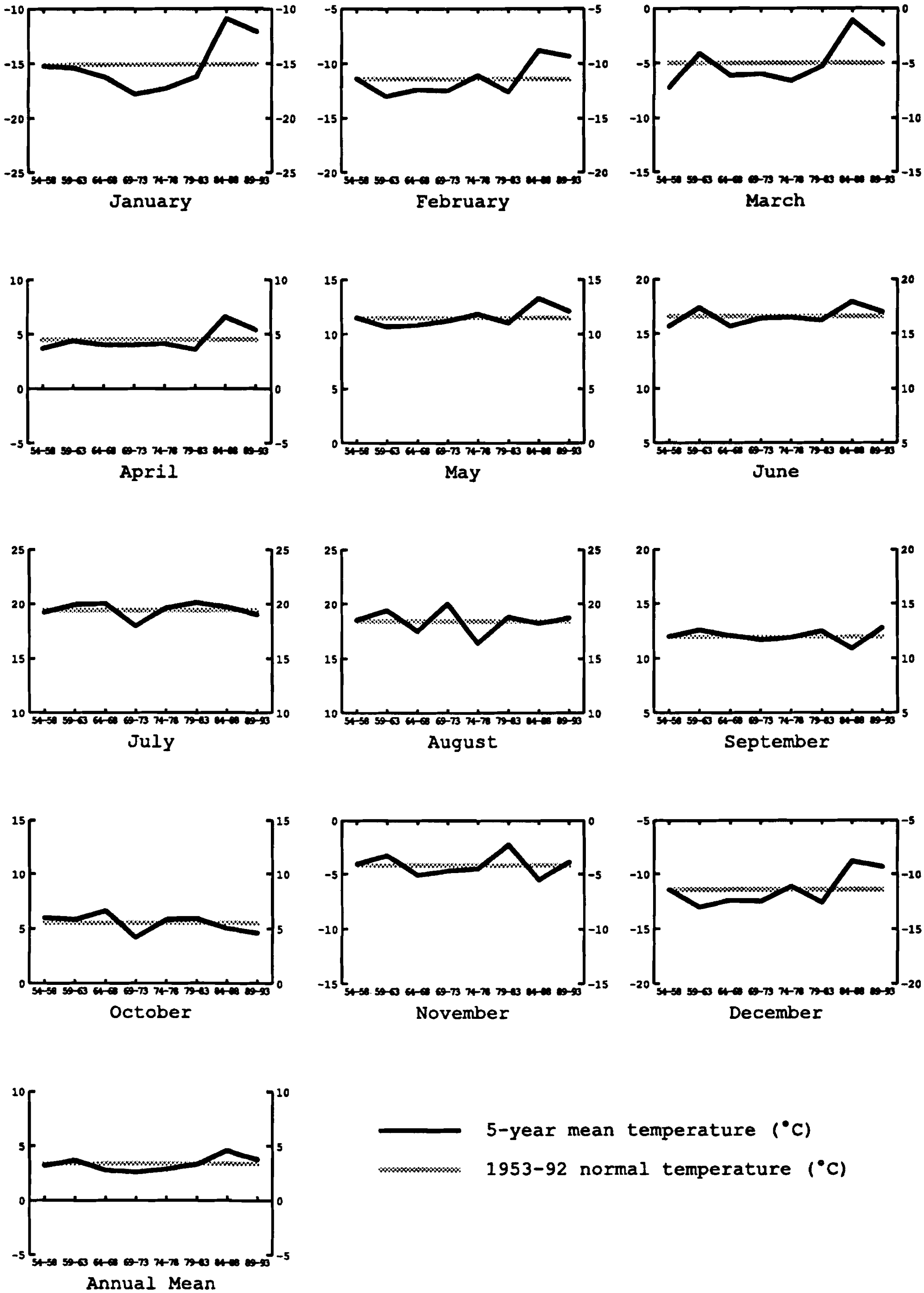

Figure C.1.2: Weyburn temperatures by month. Plotted values represent five-year averages of daily means.

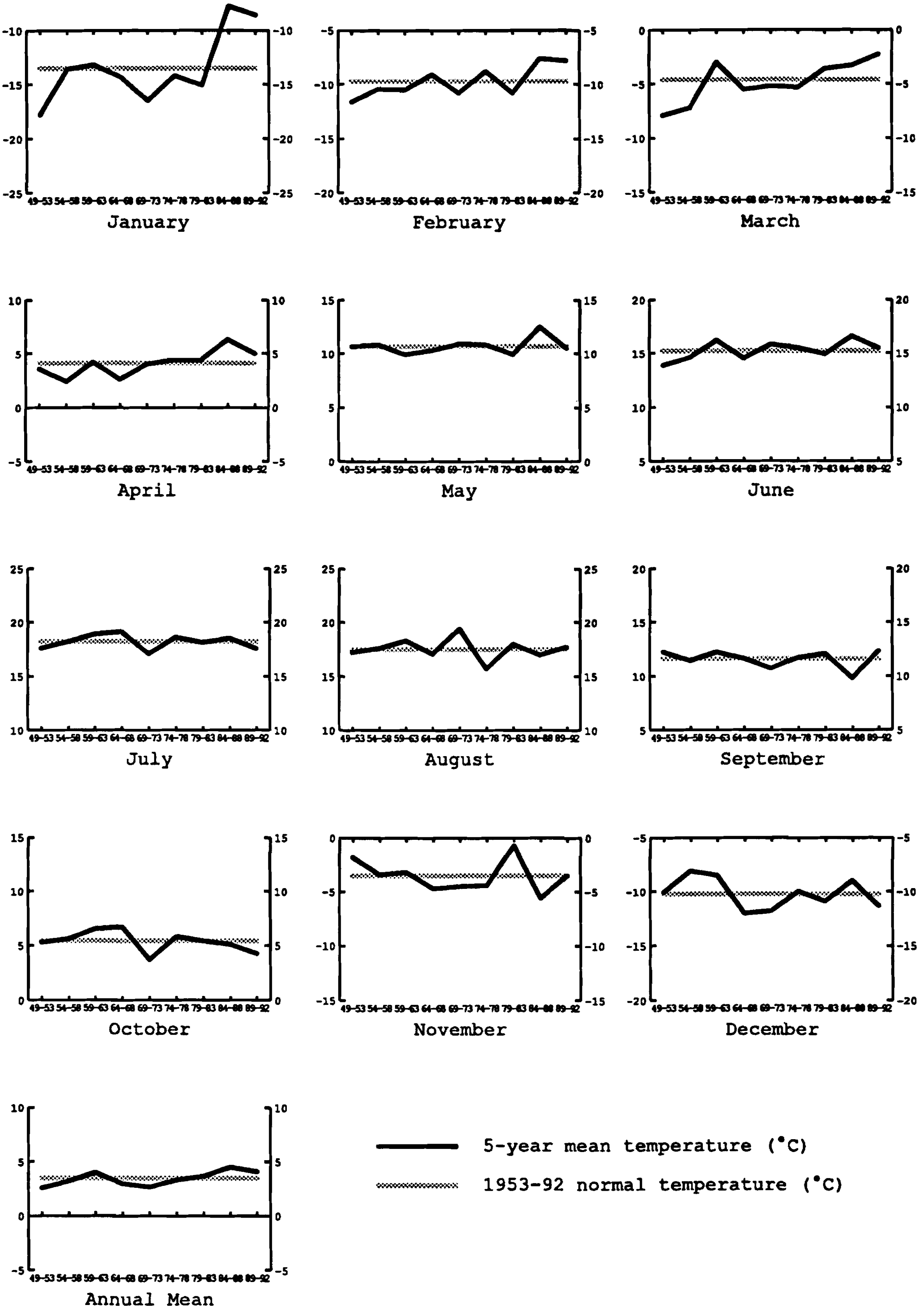

Figure C.1.3: Swift Current temperatures by month. Plotted values represent five-year averages of daily means.

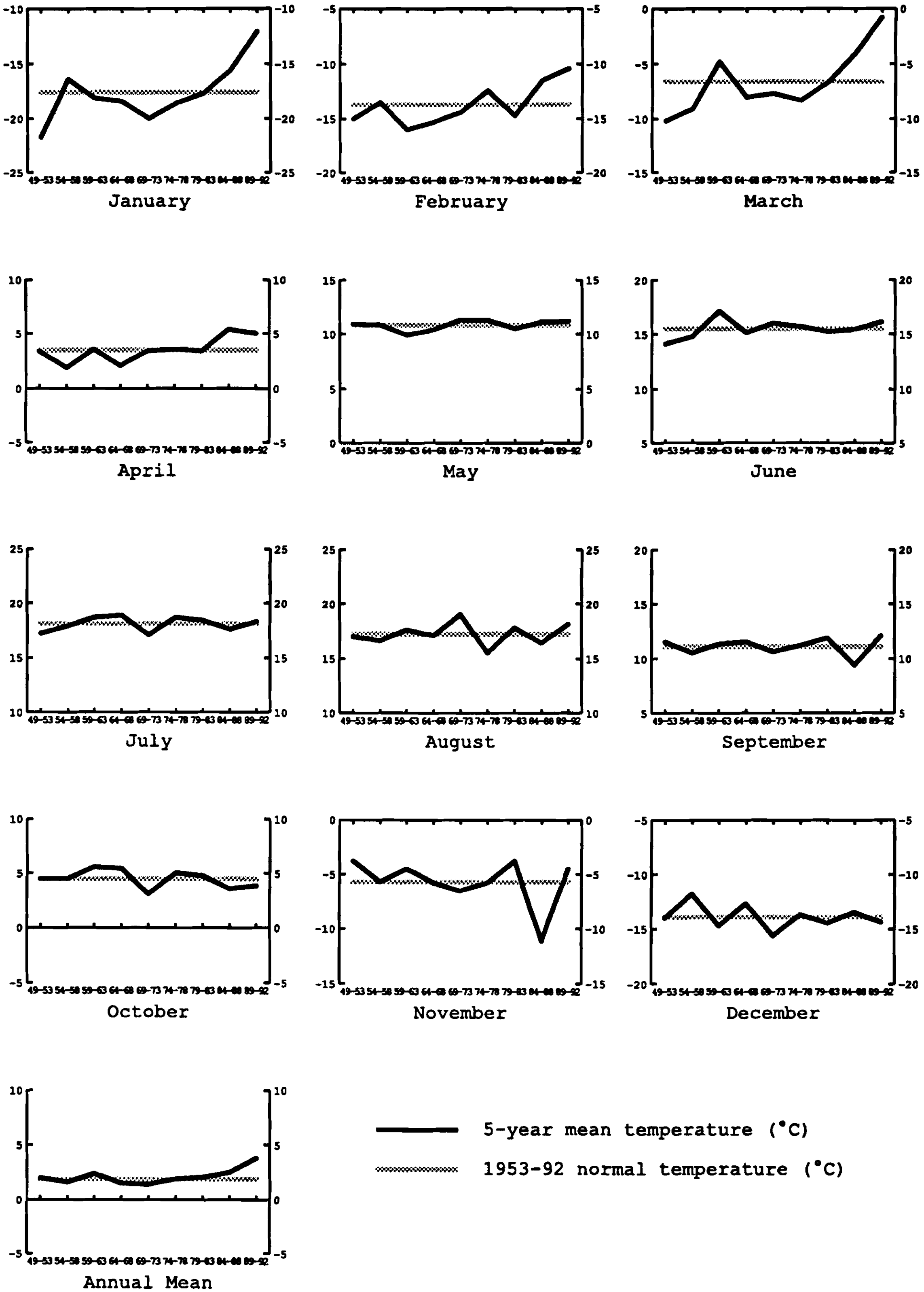

Figure C.1.4: Davidson-Outlook temperatures by month. Plotted values represent five-year averages of daily means.

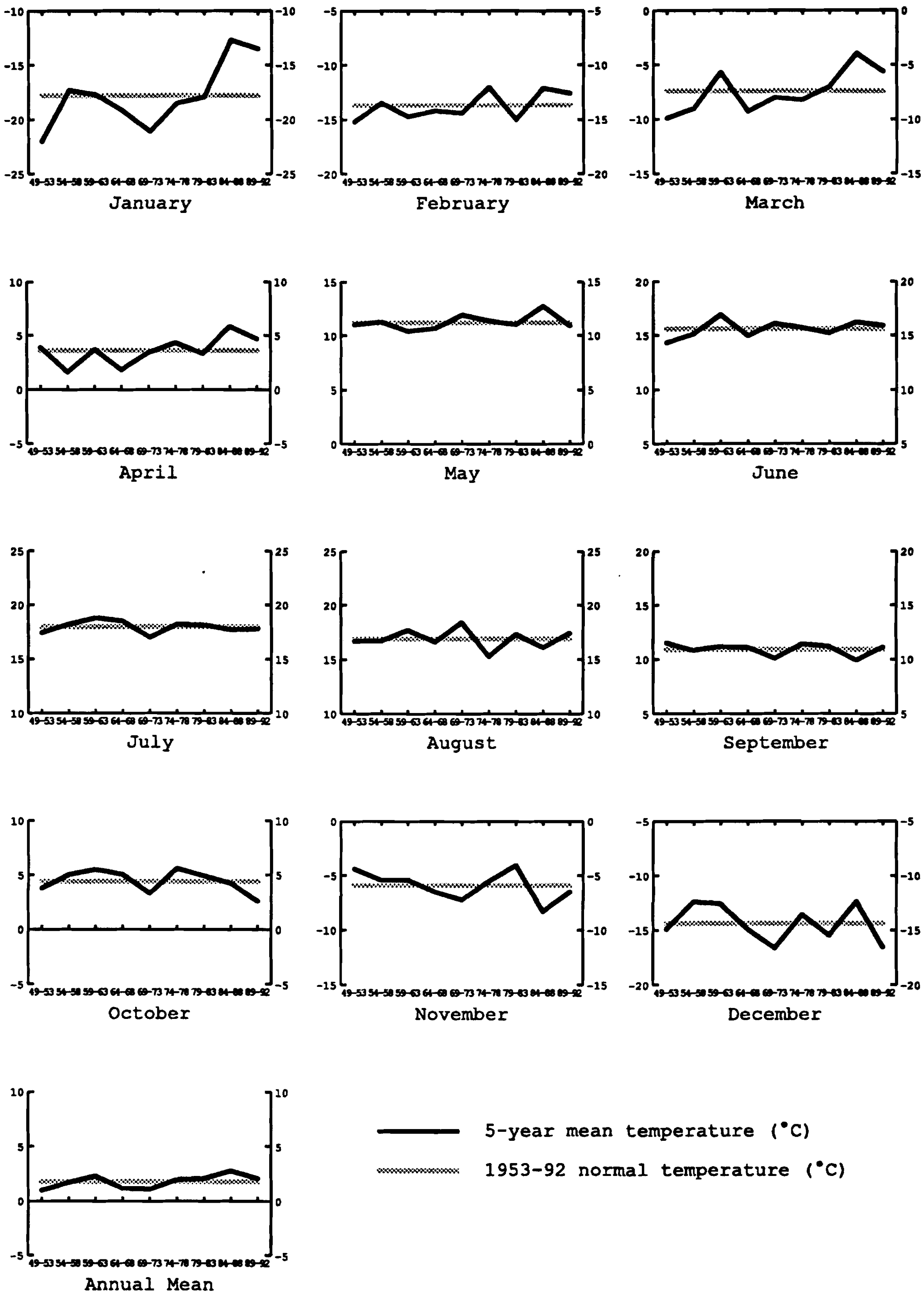

Figure C.1.5: North Battleford temperatures by month. Plotted values represent five-year averages of daily means.

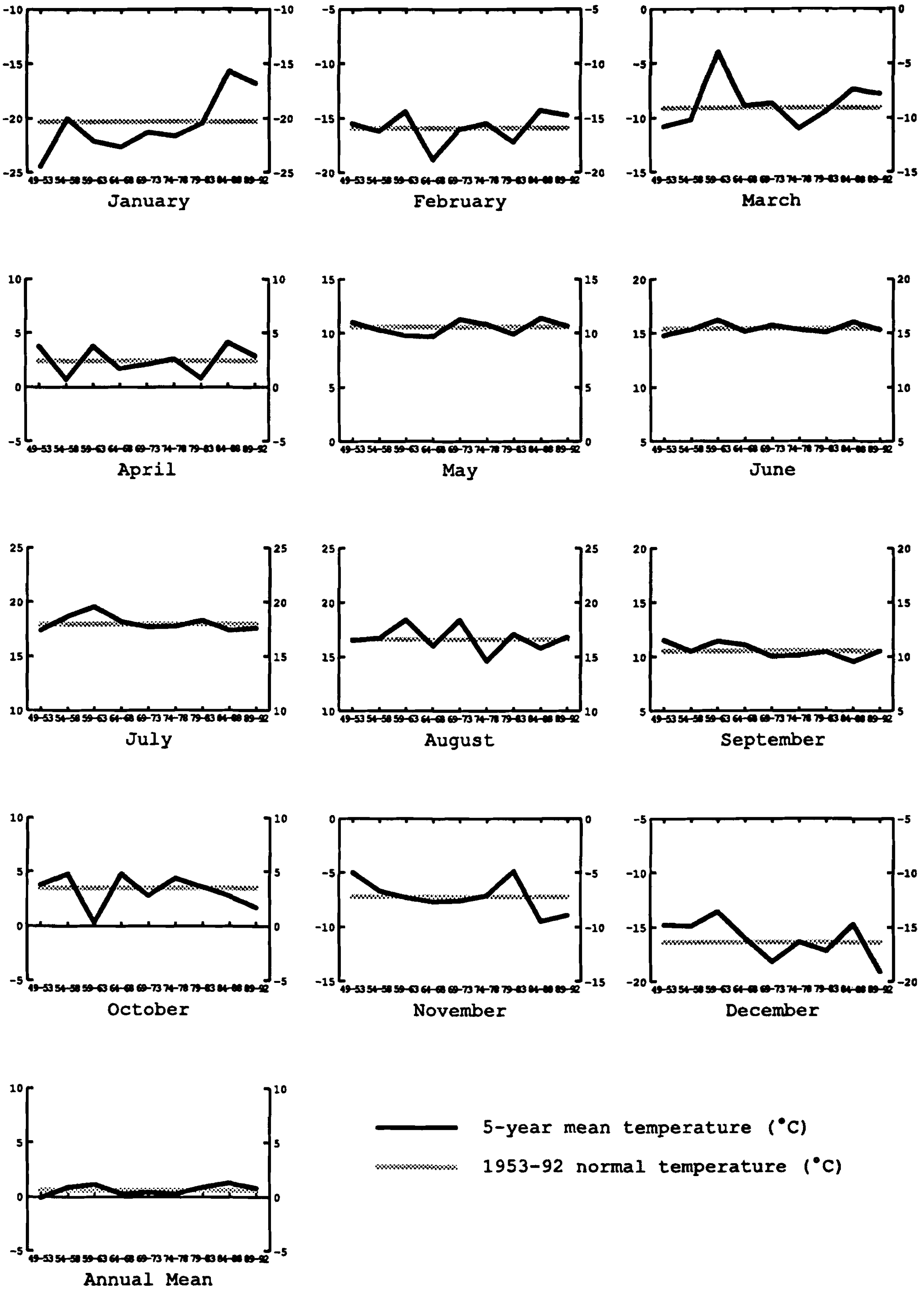

Figure C.1.6: Nipawin temperatures by month.
Plotted values represent five-year averages of daily means.

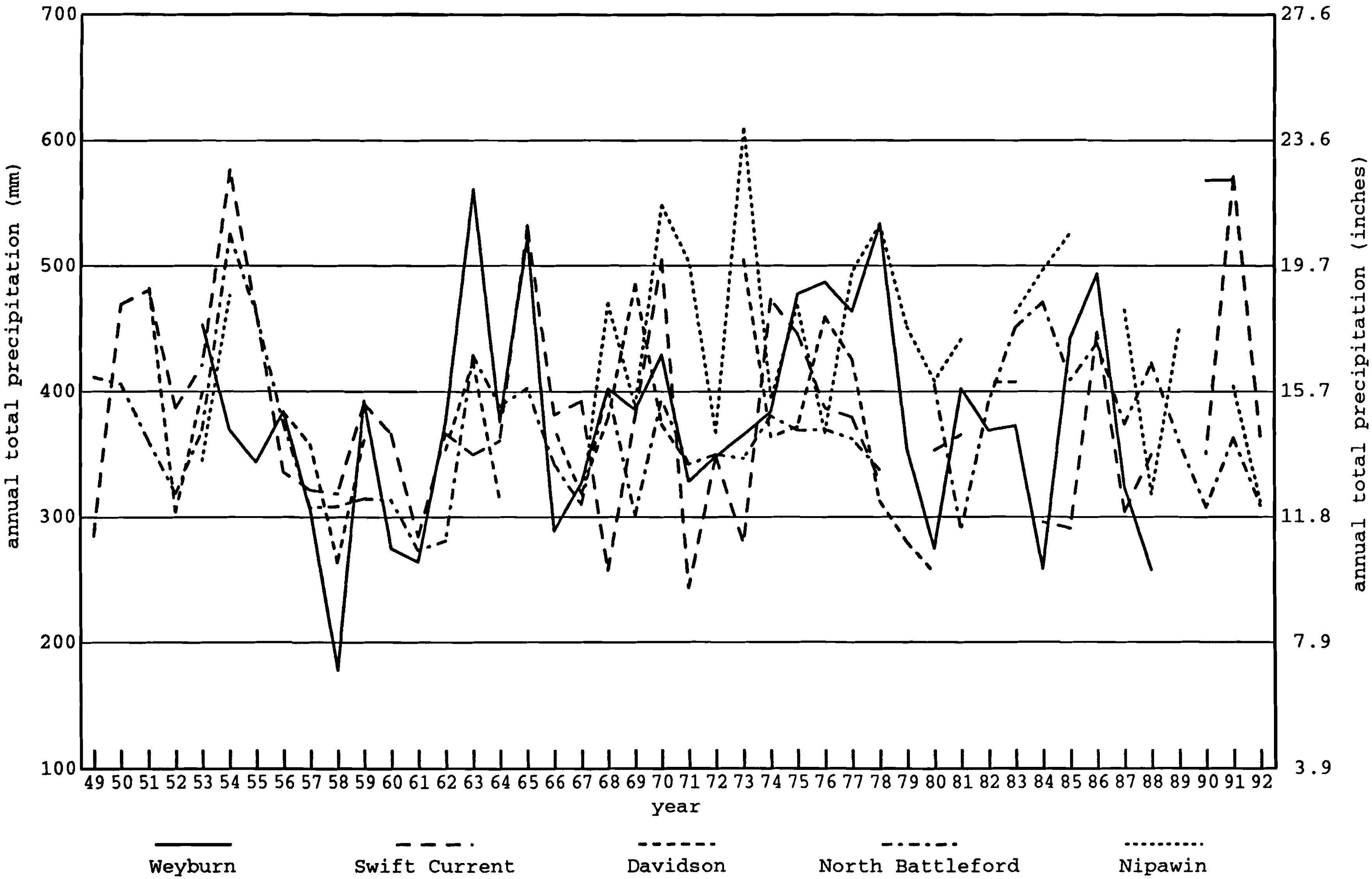

Figure C.2.1: Annual total precipitation for selected locations, 1949-92.

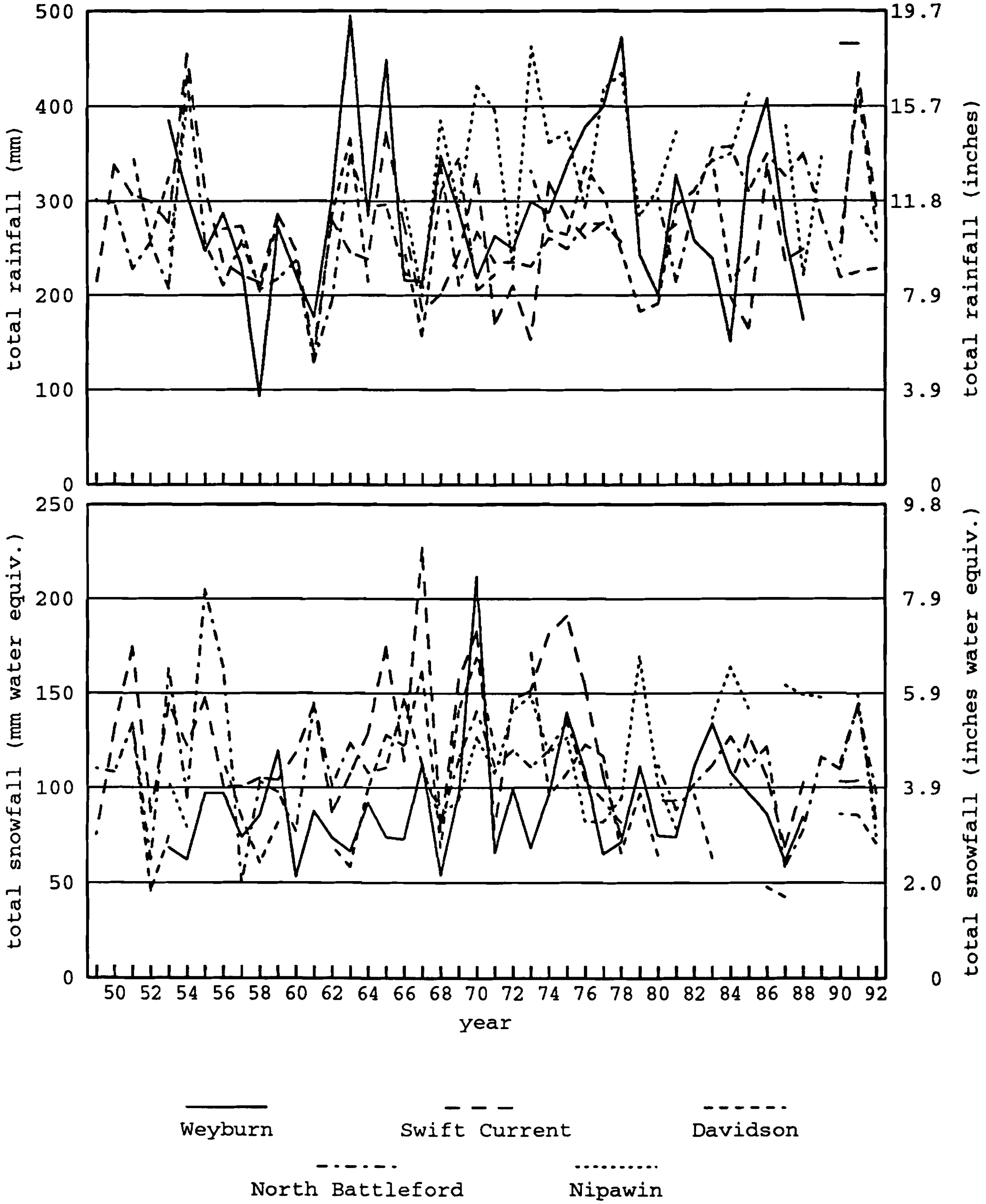

Figure C.2.2: Total rainfall (top) and snowfall (lower) for selected locations, 1949-92.

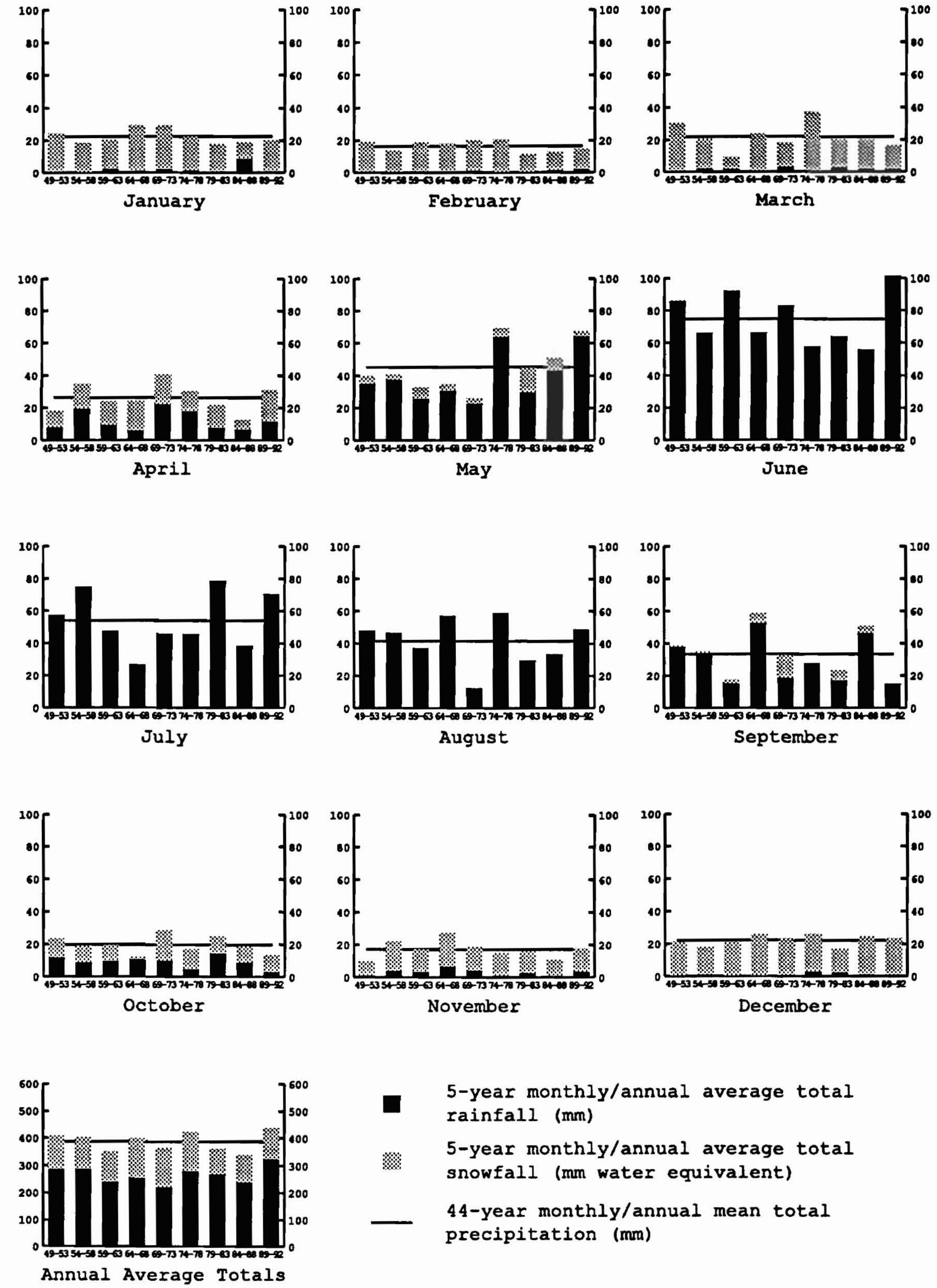

Figure C.2.4: Swift Current precipitation by month. Plotted values represent five-year averages of monthly totals.

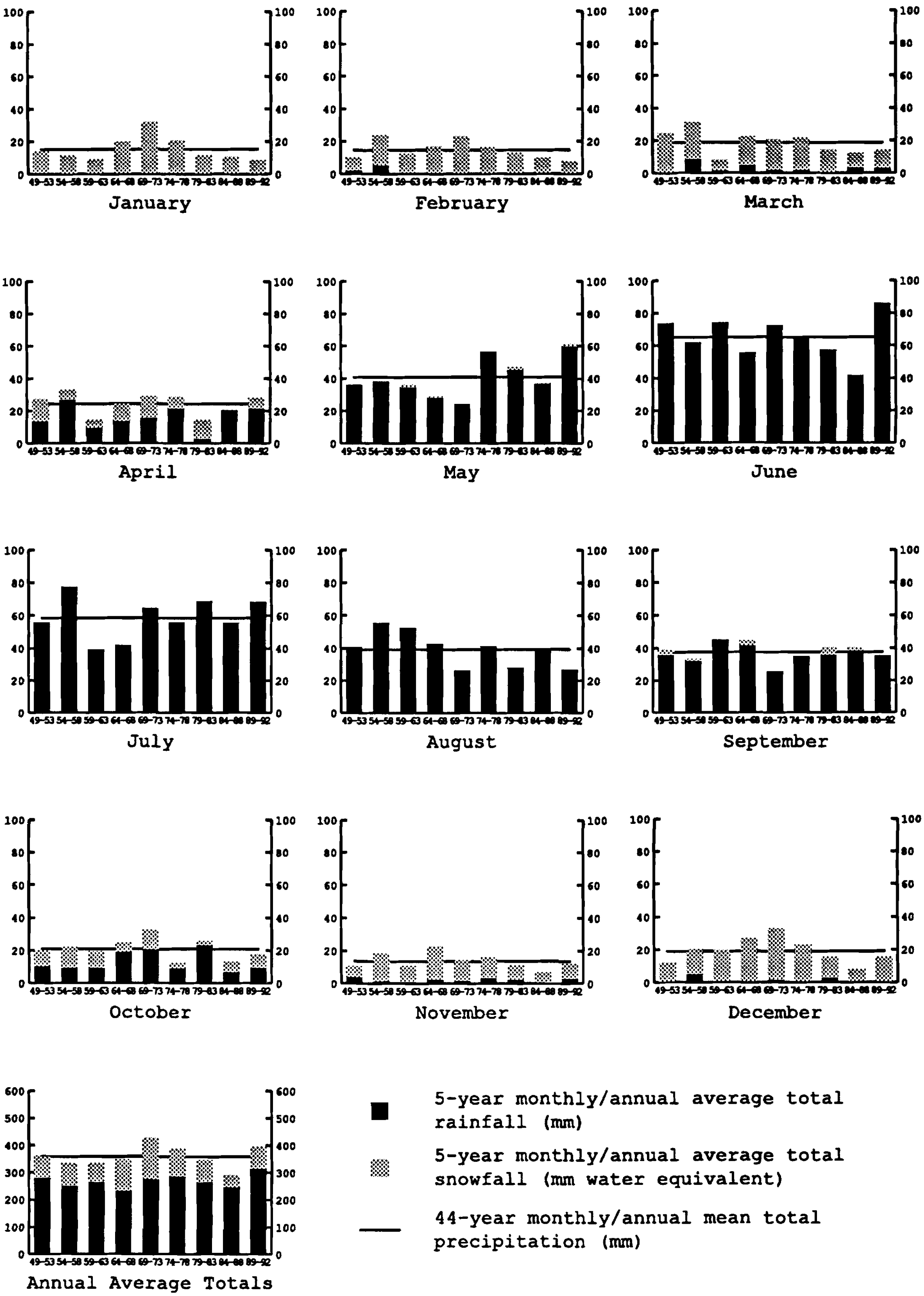

Figure C.2.5: Davidson precipitation by month. Plotted values represent five-year averages of monthly totals.

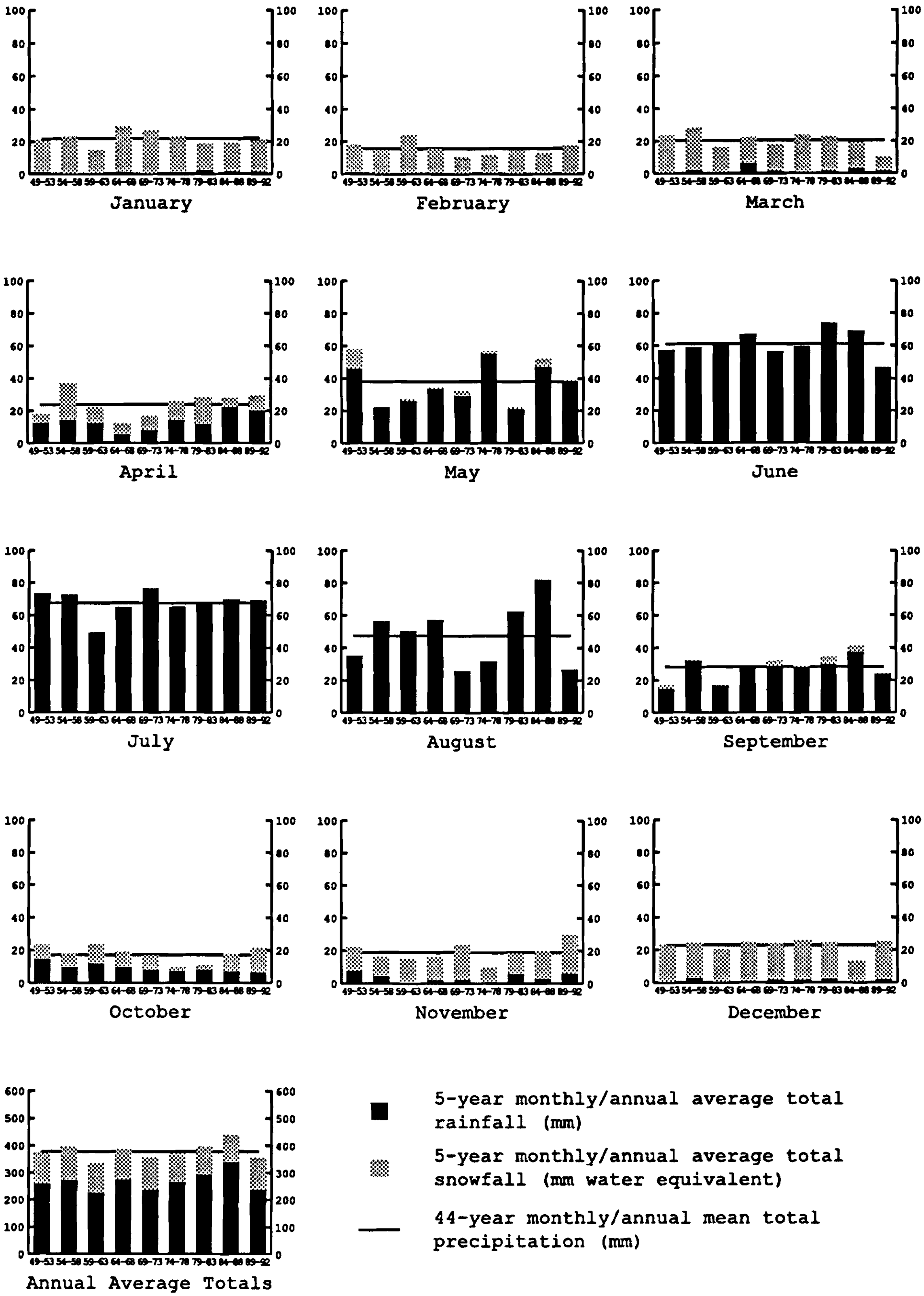

Figure C.2.6: North Battleford precipitation by month. Plotted values represent five-year averages of monthly totals.

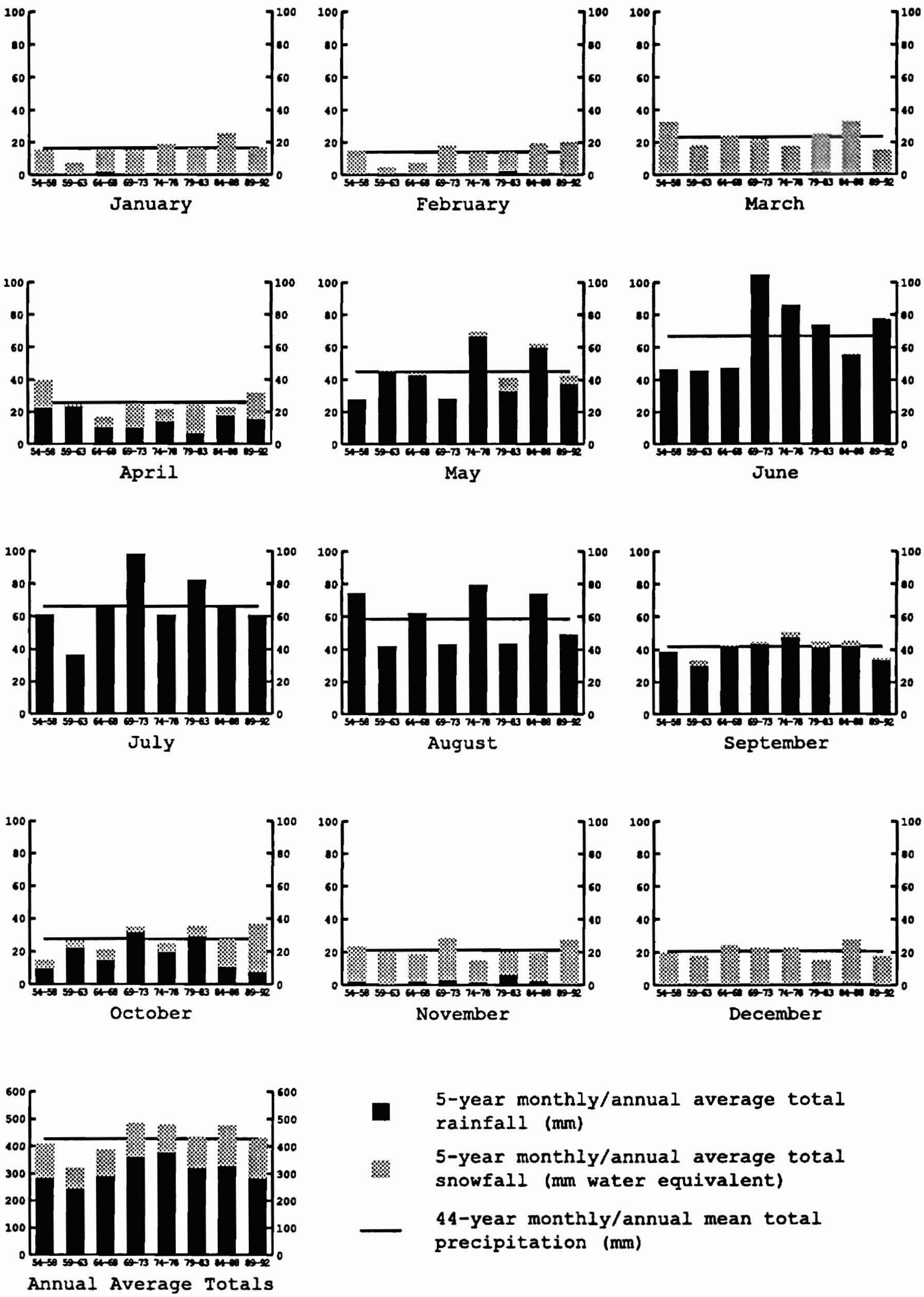

Figure C.2.7: Nipawin precipitation by month. Plotted values represent five-year averages of monthly totals.

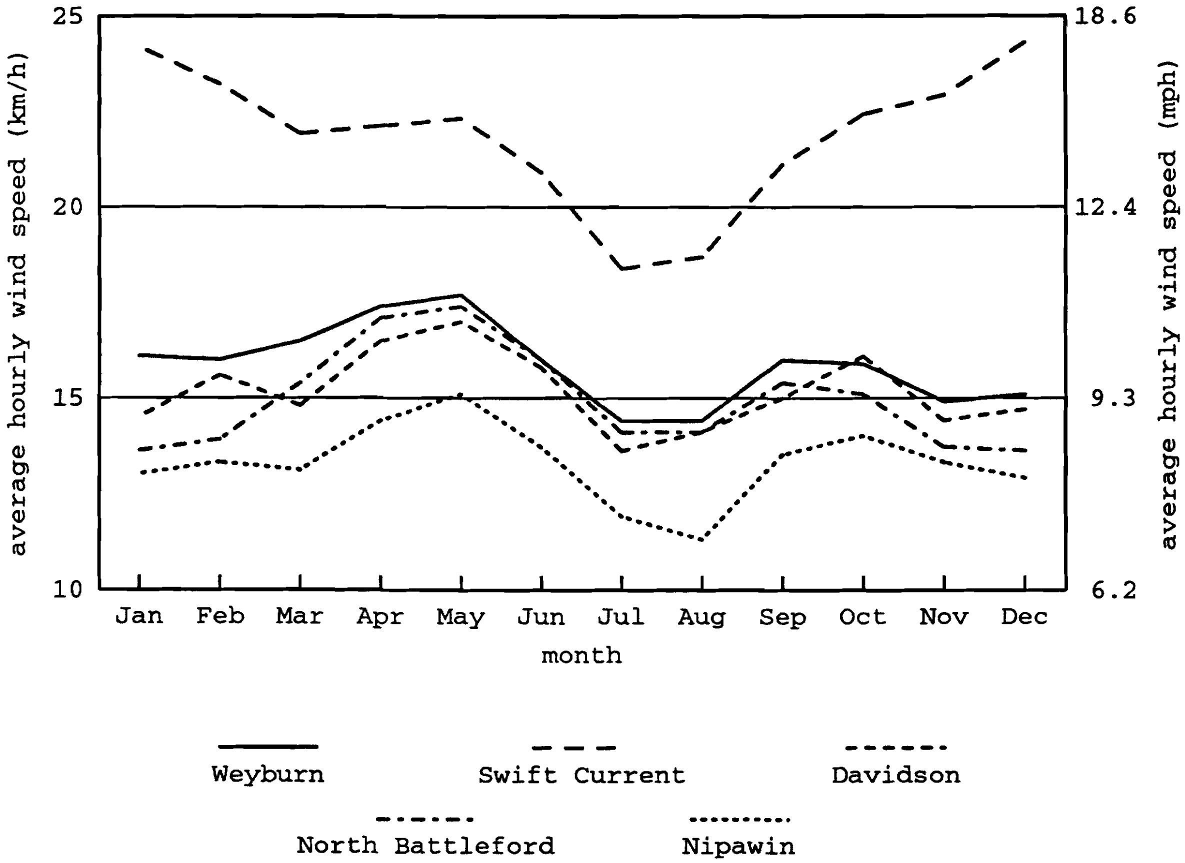

Figure C.3.1: Normal hourly wind speed (by month) for selected locations.

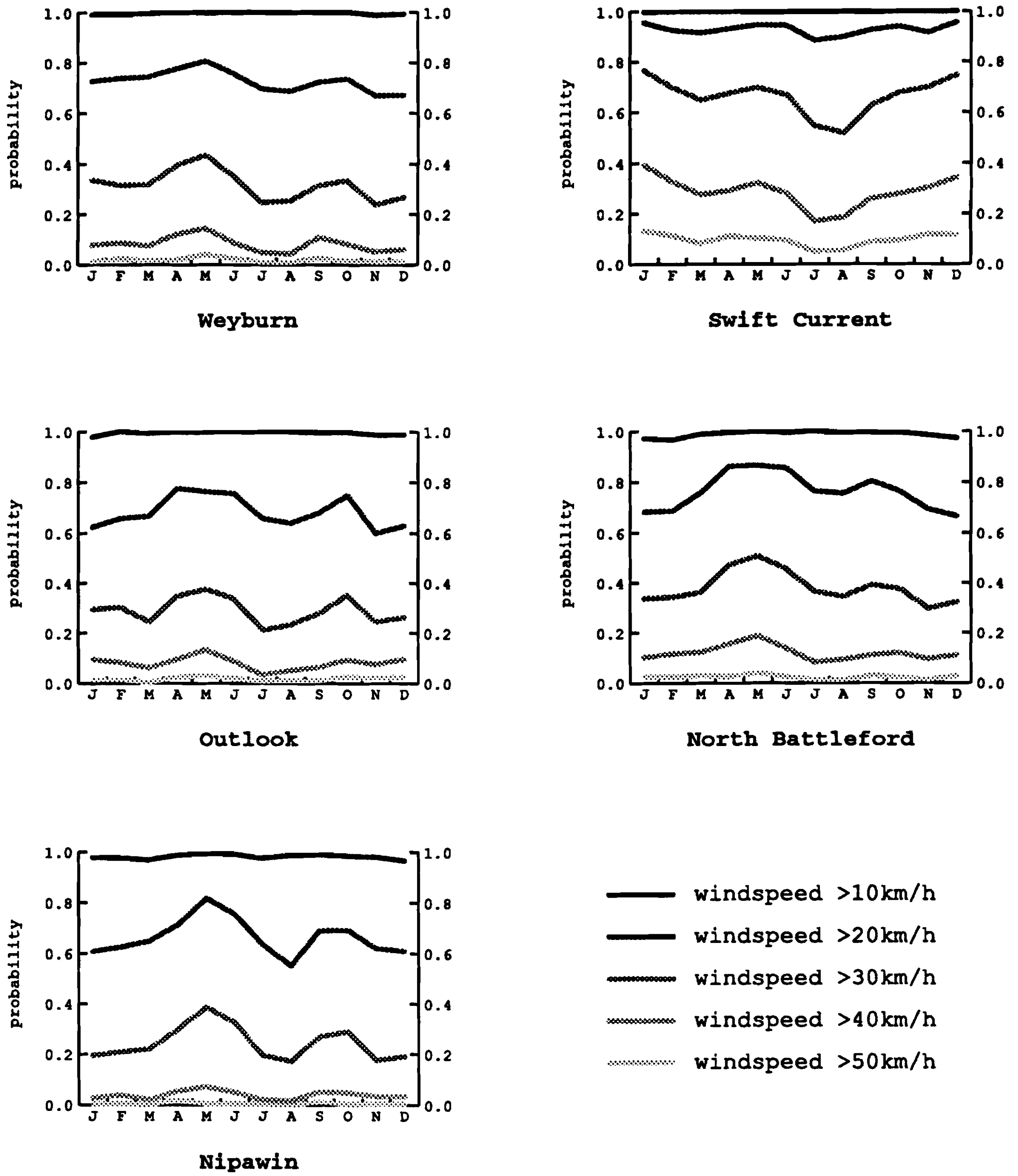

Figure C.3.2: Probability that wind will exceed a certain speed for at least one hour on any given day for selected locations (by month).

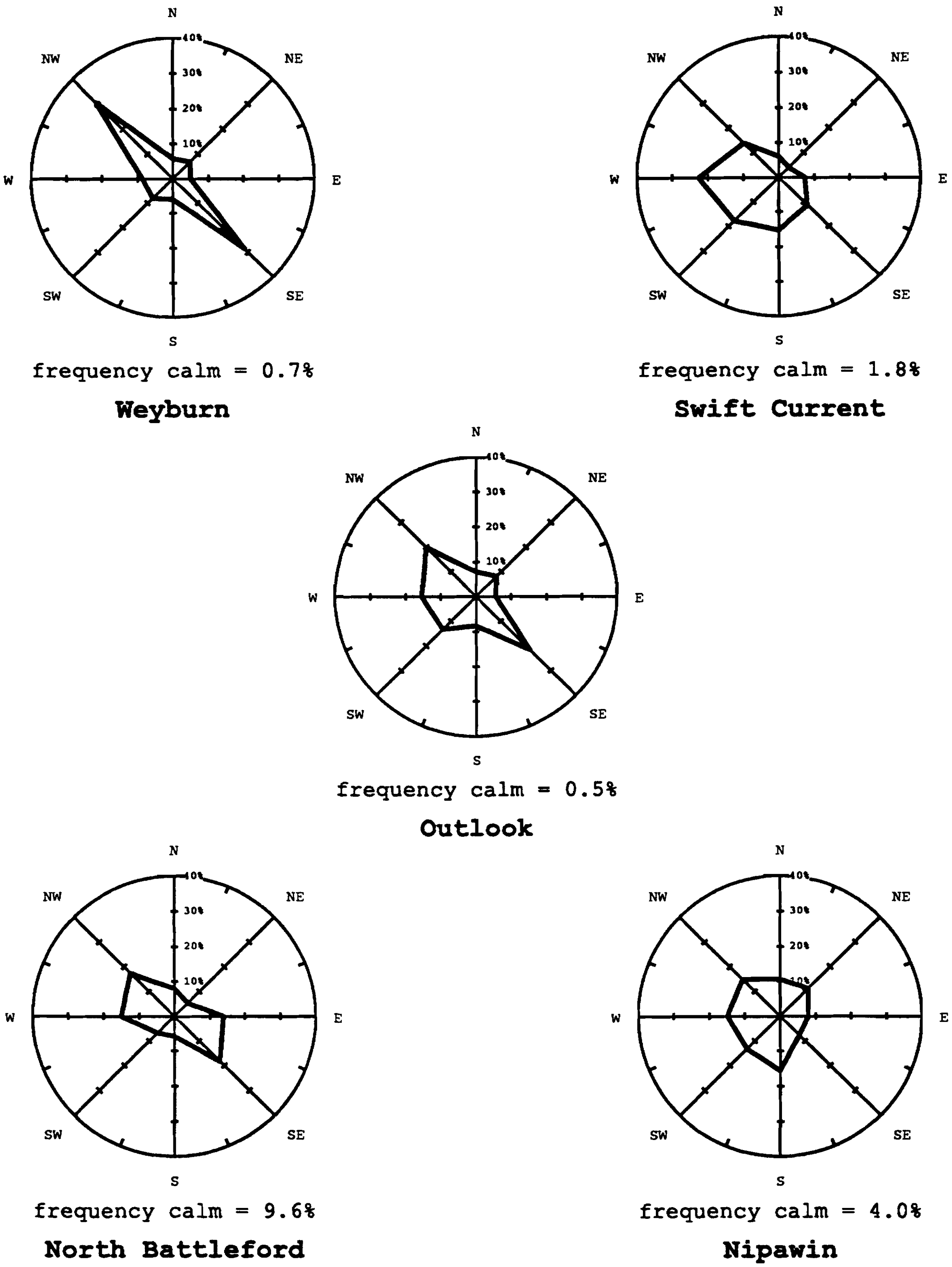

Figure C.3.3: Normal wind direction frequency for selected locations (expressed as % of hours).

Appendix D
Wind Erosion Risk

Wind erosion risk is an important indicator of the potential usefulness of field shelterbelts. It measures the combined influences of local soil texture, wind velocity, and soil moisture on potential soil movement. The Agriculture Canada *Wind Erosion Risk Map – Saskatchewan* has been used descriptively and analytically in Chapters 3 and 6 of this study. This map is based on an index of wind erosion risk developed by Coote and Padbury (1987) which may be explained as follows:

$$E = KC\left(V_*^2 - \gamma W^2\right)^{1.5}$$

where:
- E = maximum instantaneous soil movement by wind (dimensionless)
- K = surface roughness and aggregation factor (dimensionless)
- C = factor representing soil resistance to movement by wind (dimensionless)
- V_*^2 = drag velocity of wind at the soil surface (cm/s)
- γ = soil moisture shear resistance (set as a constant at 5,000)
- W = available moisture of the surface soil (m^3 water / m^{-3} soil)

E is effectively an index of a surface soil's susceptibility to eolian erosion. Coote and Padbury (1987) have assigned the following erosion risk classes:

Wind Erosion Risk Class	**Value of E**
Negligible	<100
Low	100-249
Moderate	250-399
High	400-699
Severe	>700

Values of K and C have been set for various Canadian Prairie soil textures as:

Soil Group	Surface Texture Class	K	C
Sands	Sand	1.00	0.00433
	Loamy sand	0.75	0.00421
	Fine sand	1.00	0.00433
	Loamy fine sand	0.75	0.00421
	Gravelly sand	0.70	0.00433
Sandy Loams	Sandy loam	0.60	0.00393
	Fine sandy loam	0.50	0.00389
	Gravelly sandy loam	0.45	0.00393
Loams	Loam	0.20	0.00357
	Very fine sandy loam	0.40	0.00398
	Silt loam	0.20	0.00361
Clay Loams	Clay loam	0.18	0.00329
	Silty clay loam	0.19	0.00309
Clays	Sandy clay	0.50	0.00300
	Silty clay	0.50	0.00277
	Clay	0.60	0.00245
	Heavy clay	0.65	0.00197

V_* represents the wind drag component. Measured velocities are standardized at 2 metres above the surface.

$$V_* = \frac{27.78(V_2)}{5.75\log\left(2/k\right)}$$

where: V_2 = wind velocity (km/h) at 2 m above the surface
k = height at which velocity is effectively zero (assumed to be 0.00025 m)

Soil moisture values (W) represent Versatile Soil Moisture Budget calculations. This infers a wheat-fallow rotation cropping system, with meteorological inputs averaged from data collected on the first days of April, May, and June for the seeding year.

Appendix E
Agriculture Statistics

Agricultural practices and production influence an individual producer's attitude towards field shelterbelts. Land-use, cropping systems and productive return all depend upon local physiographic conditions and therefore vary spatially and historically.

Some important agricultural characteristics have been outlined in the text of Chapters 3 and 6. This appendix supplements that information with a selection of comparative statistics, specifically the following: agricultural land-use, crop preference, and historical commodity product fluctuation. The data represents survey results compiled by Statistics Canada from 1951 through 1996 and is presented graphically in Figures E.1 through E.3. The basis of spatial representation is the case-study areas of Chapter 6. The location maps of that chapter may be consulted to compare the case study, versus census division, boundaries. The case study locations and their corresponding census areal units are listed in Table E.1.

Table E.1: Case study area – census division cross-reference.

Case Study Location Name	**Census Division**	**Census Sub-Division (SRM)**	**Location Ref. (Chapter 5 Figure No.)**
Midale	2	36	5.2.1
Cadillac	4	107	5.3.1
Davidson-Bladworth	11	253	5.4.1
Wilkie-Unity	13	409	5.5.1
Nipawin	14	487	5.6.1

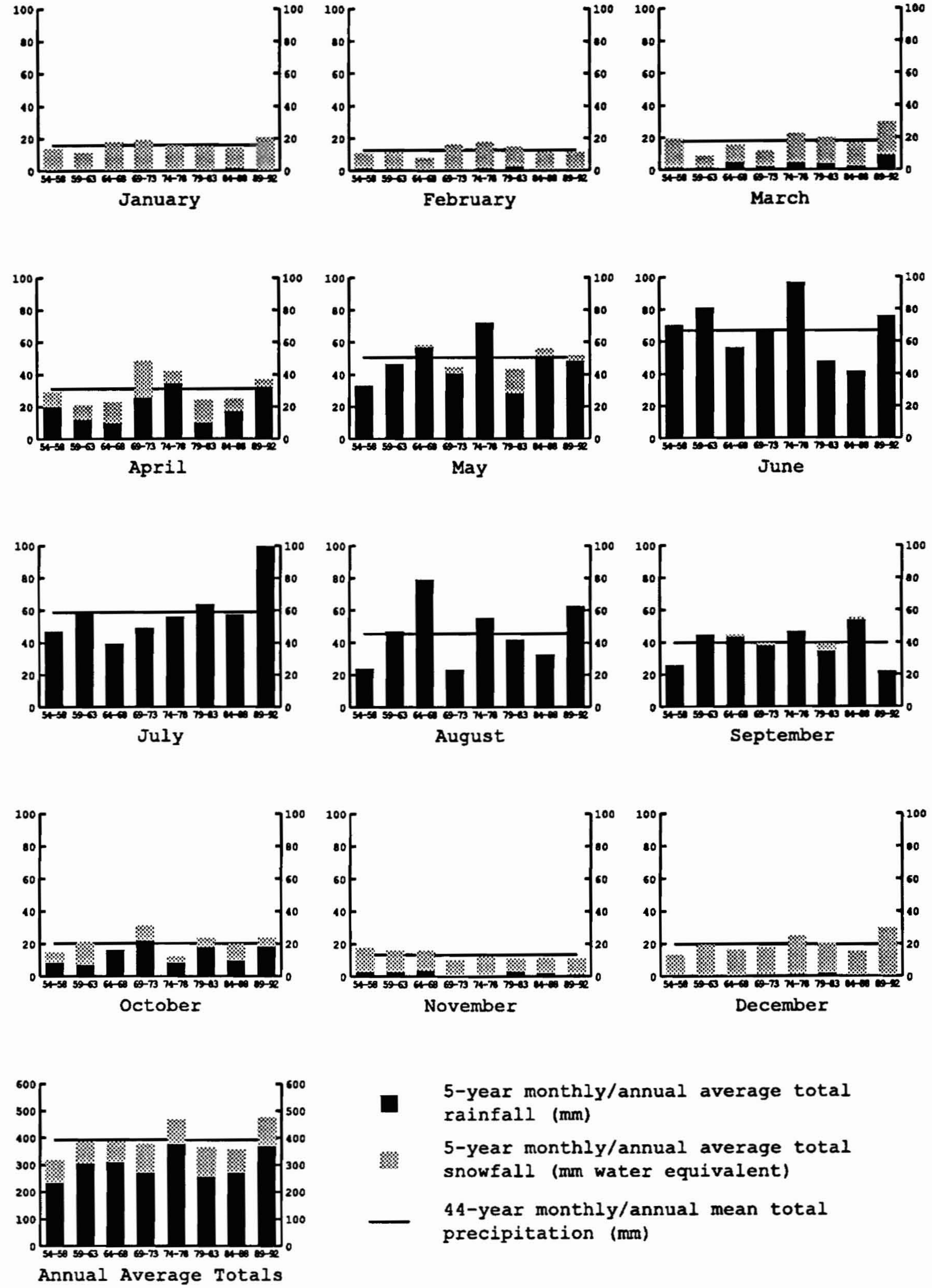

Figure C.2.3: Weyburn precipitation by month. Plotted values represent five-year averages of monthly totals.

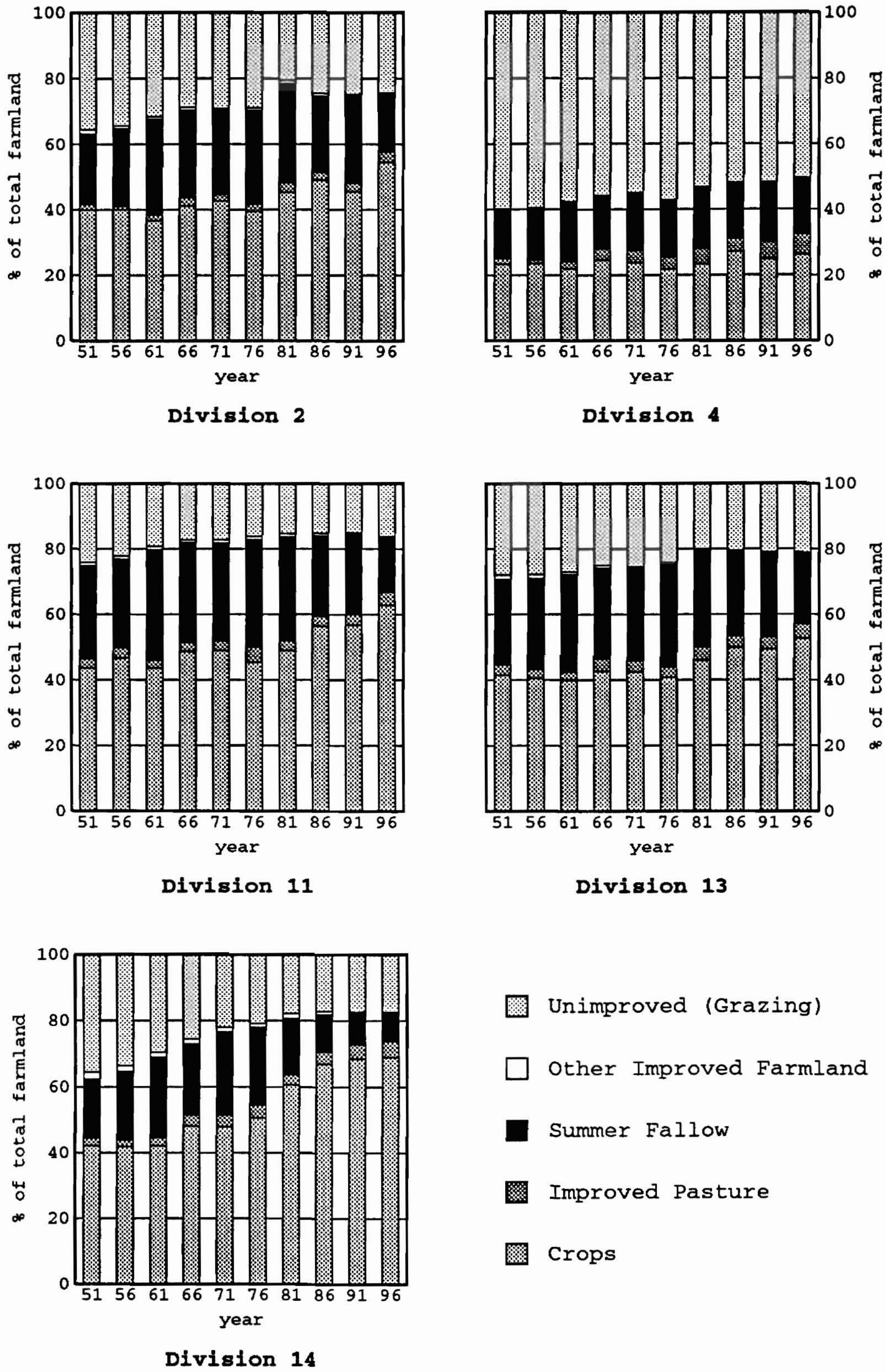

Figure E.1: Farm land-use for selected census divisions.

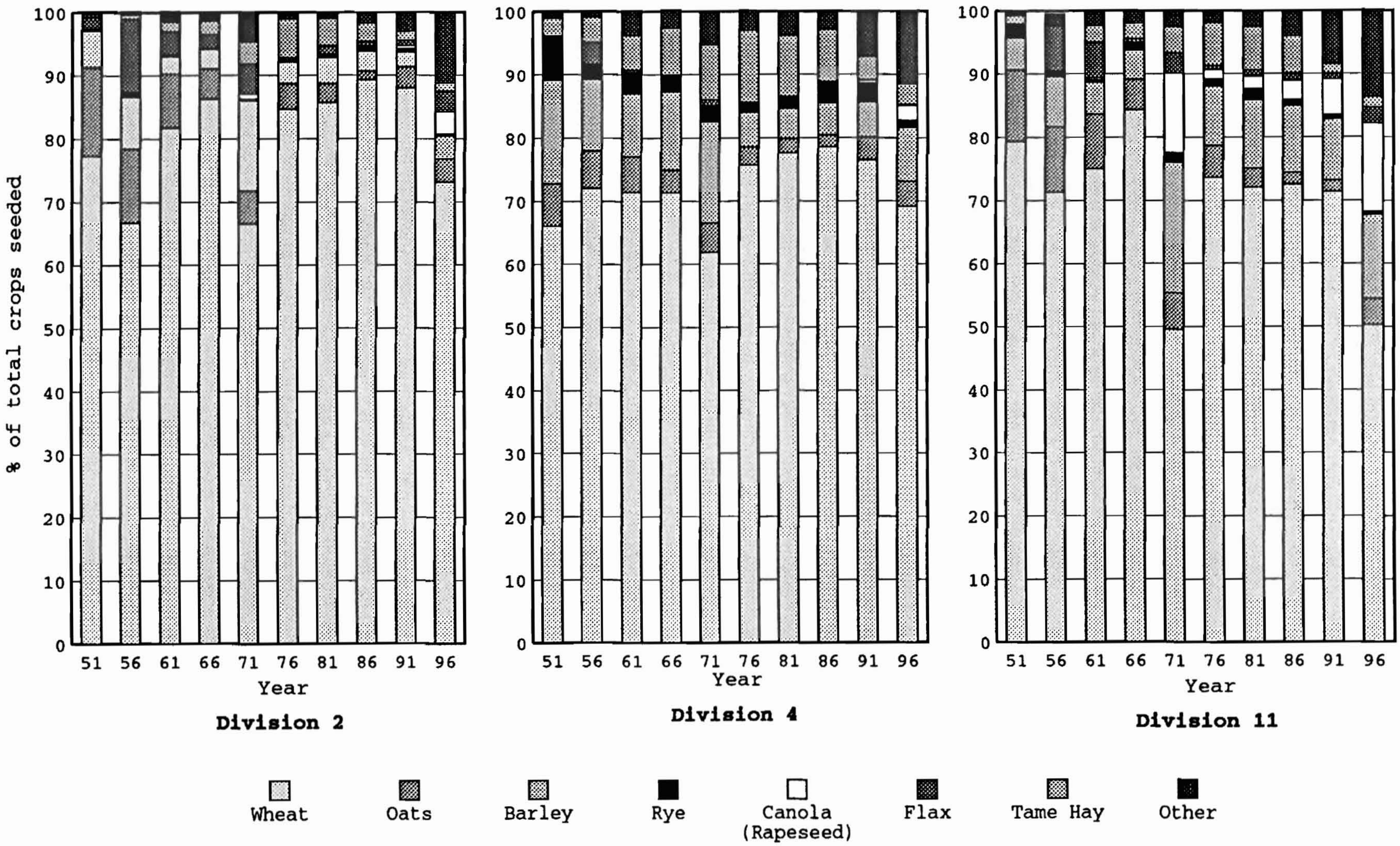

Figure E.2: Proportion of crops seeded for selected census divisions (expressed as %).

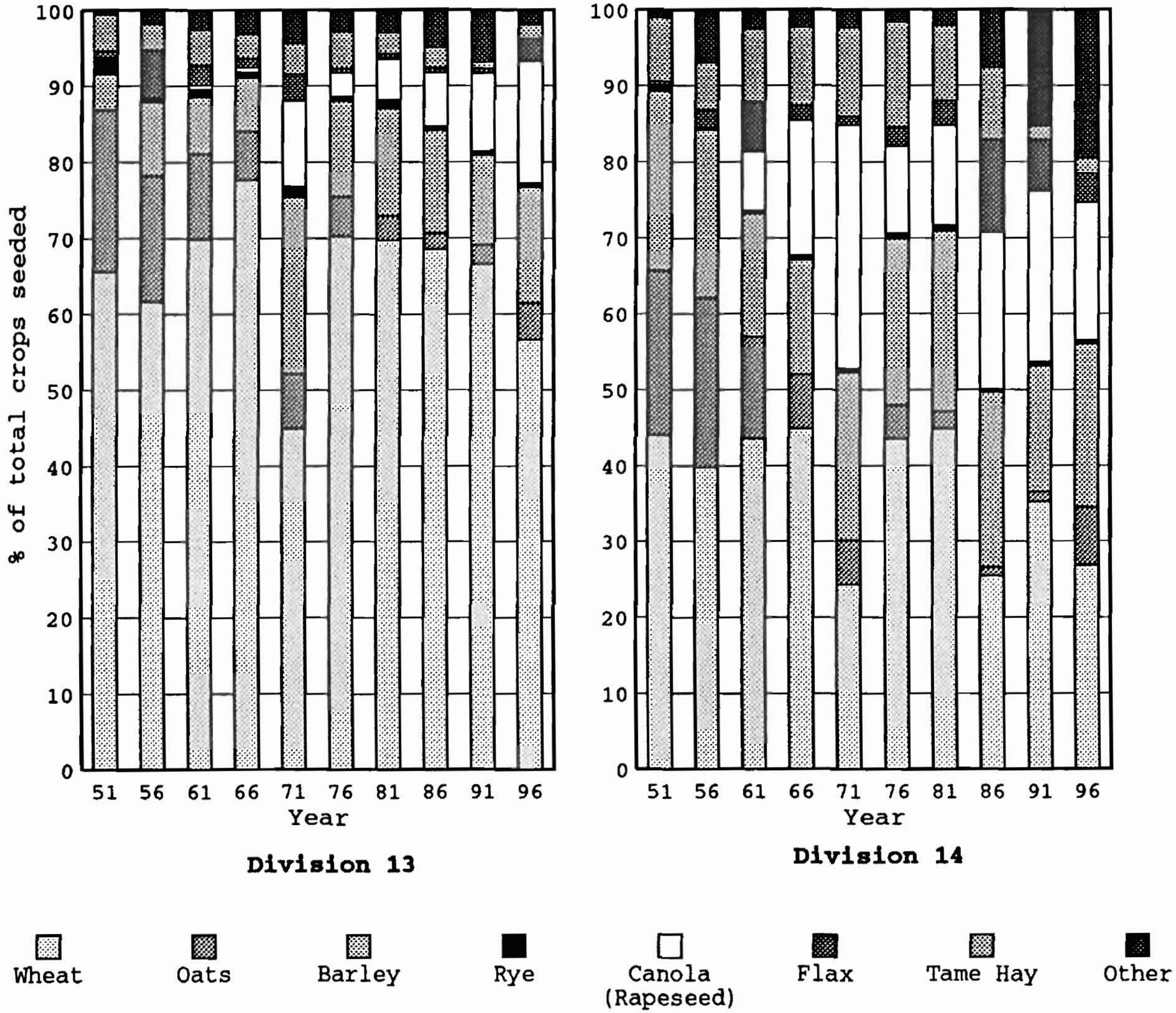

Figure E.2 continued.

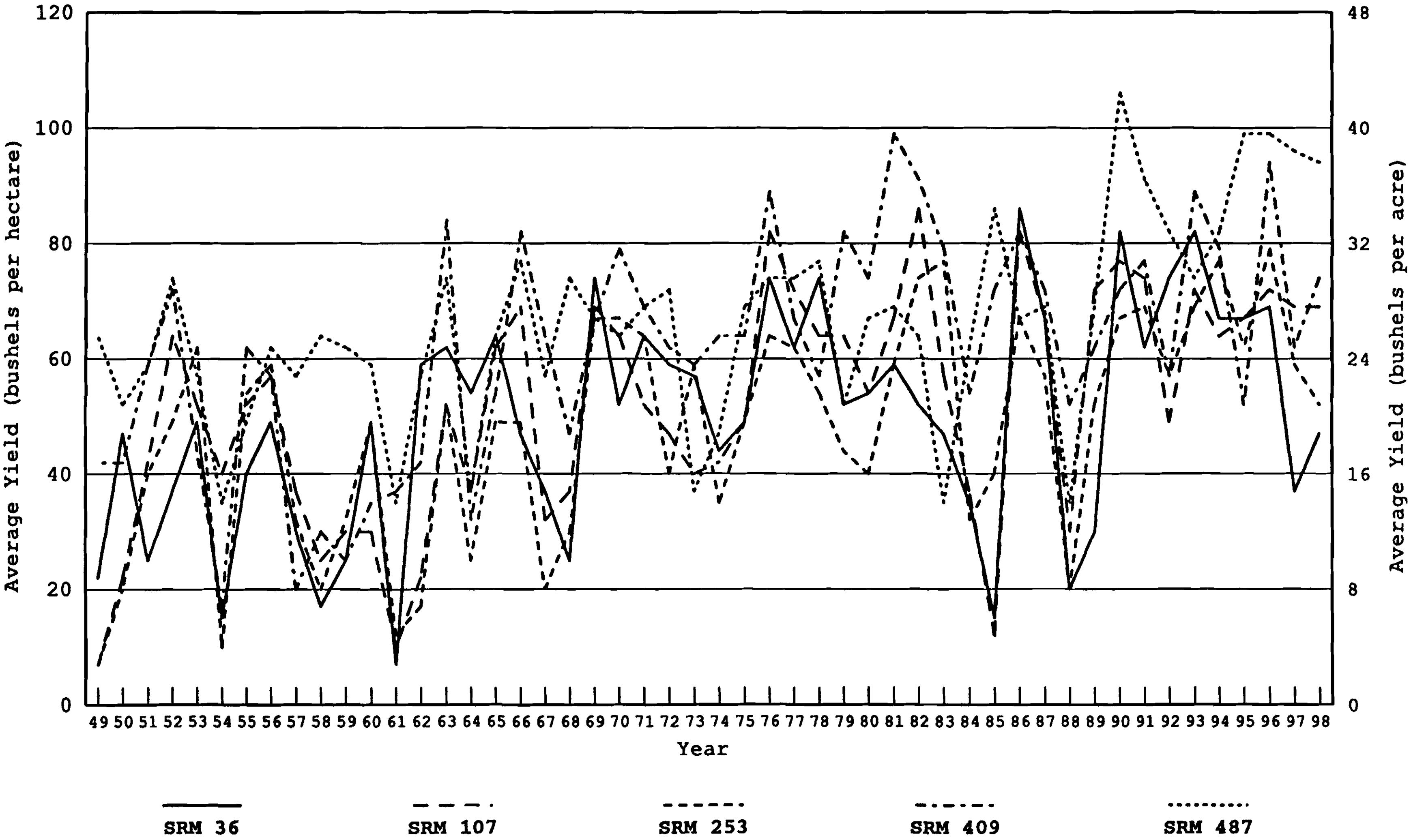

Figure E.3.1: Average wheat yield fluctuations for selected locations, 1949-98.

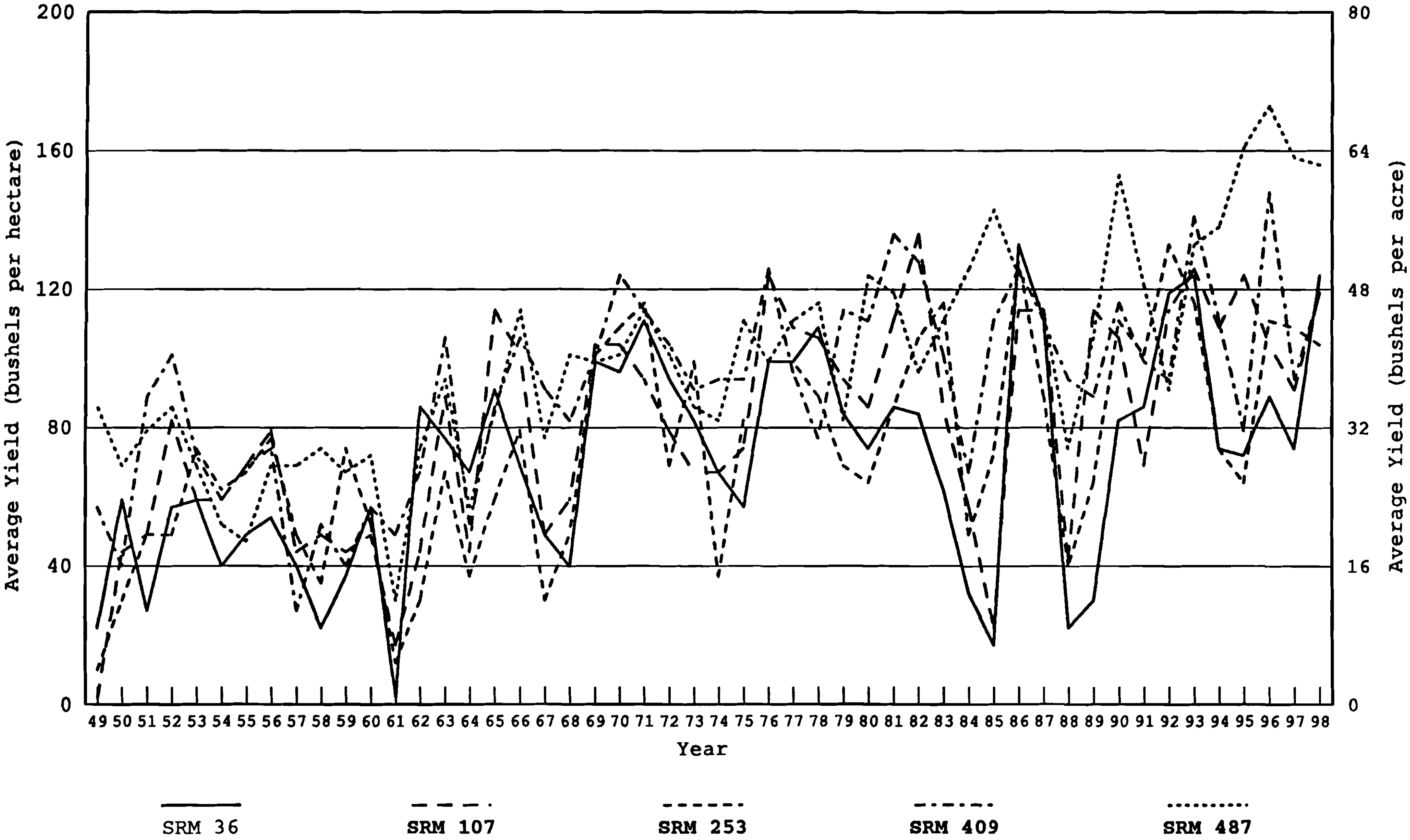

Figure E.3.2: Average barley yield fluctuations for selected locations, 1949-98.

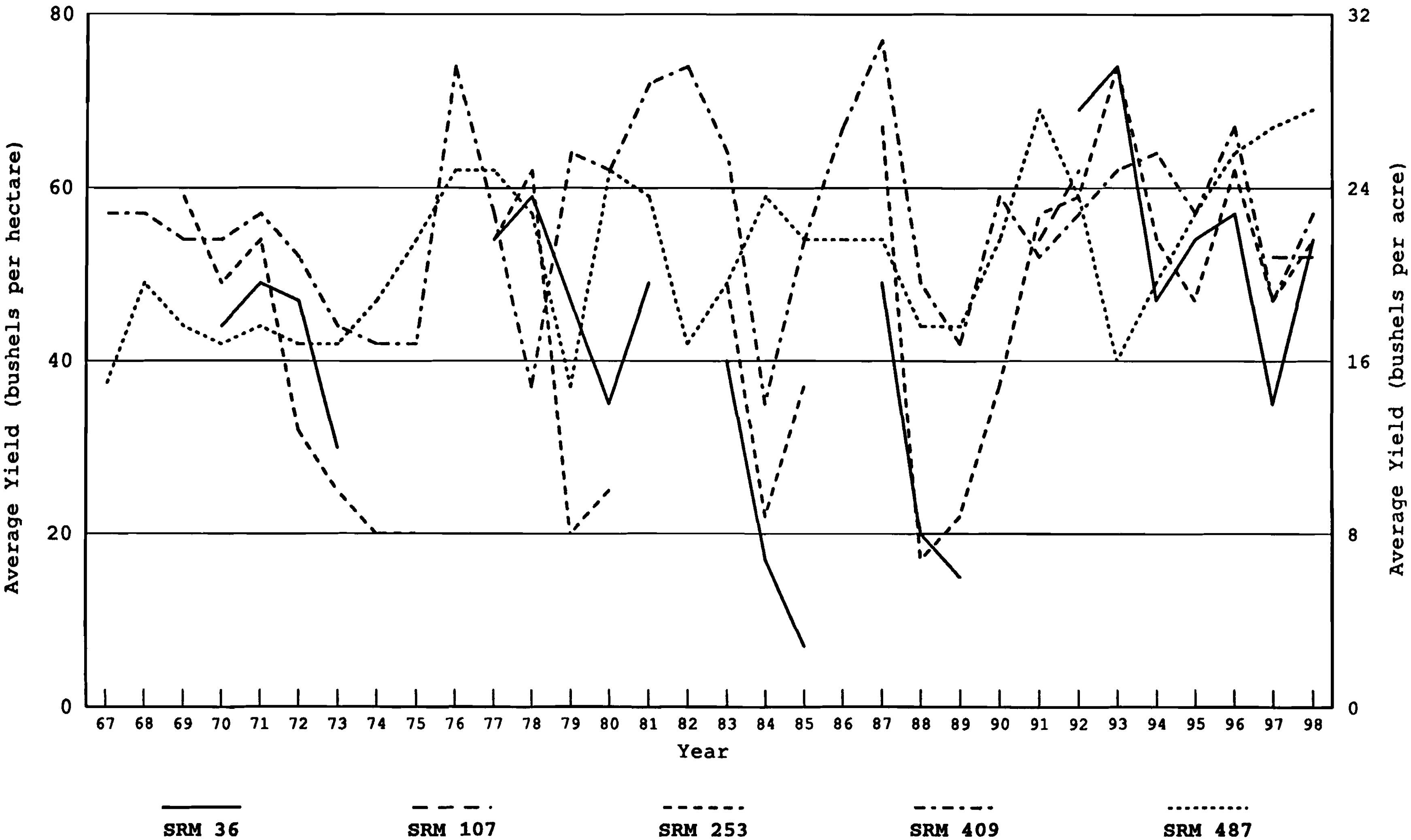

Figure E.3.3: Average canola yield fluctuations for selected locations, 1967-98.